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Characterising marine mollusc exploitation in the eastern African Iron Age: Archaeomalacological evidence from Unguja Ukuu and Fukuchani, Zanzibar

Patrick Faulkner[1*], Matthew Harris[2], Abdallah K. Ali[3], Othman Haji[3], Alison Crowther[2], Mark C. Horton[4], Nicole Boivin[5]

1 The University of Sydney, Faculty of Arts and Social Sciences, Department of Archaeology, Sydney, New South Wales, Australia

2 School of Social Science, The University of Queensland, Brisbane, Australia

3 Department of Archives, Museums and Antiquities, Zanzibar, Tanzania

4 Department of Archaeology and Anthropology, University of Bristol, Bristol, UK

5 Max Planck Institute for the Science of Human History, Jena, Germany

*Correspondence to: patrick.faulkner@sydney.edu.au

Abstract

Molluscan remains from archaeological contexts have the potential to provide information related to a range of issues, including but not limited to settlement and economic structures, and local environmental conditions. Shell deposits are ubiquitous along the eastern African coast and offshore islands, with previous archaeological research highlighting the prevalence of these deposits in conjunction with providing some discussion on the variable contribution or role of molluscs within the economy. In general, marine molluscs have been viewed as a secondary or fall-back resource with largely opportunistic harvesting in the intertidal zone. In addition, there is a general expectation that there would be significant variability in exploitation depending on settlement structure, the availability of domesticates, and with status differences. With few exceptions, however, the scale and resolution of archaeomalacological analyses across the broader region have tended to be

relatively coarse, making it difficult to adequately assess these interpretations. Here we consider these issues based on detailed analyses of the sites of Unguja Ukuu and Fukuchani situated on the island of Unguja (Zanzibar), providing an assessment of the relative importance of the exploited taxa and ecological niches, in combination with species richness and diversity. These analyses provide a comparative framework for other sites in the region, and a baseline understanding of human interactions with coastal environments through molluscan exploitation.

Keywords
Archaeomalacology; coastal archaeology; foraging; Iron Age; subsistence; Swahili coast

1. Introduction

The nature of prehistoric human occupation of coastal environments, and the role of resources contained within these environments in past economies, have been heavily debated for many decades. One position saw coastal and marine environments being largely ignored, until increasing competition for terrestrial resources in combination with increasing populations forced a reorientation of humans to focus on more marginal habitats, particularly following the Last Glacial Maximum (e.g. Cohen, 1977; Osborn, 1977). The alternative and now more influential perspective emphasises the attractiveness of dynamic and diverse coastal ecosystems, and in particular the general productivity and economic potential of the intertidal zone (Bailey, 2004; Erlandson, 1994; Perlman, 1980; Meehan, 1977; Yesner, 1980; and Erlandson, 2001 for a detailed overview of these issues). In fact, many of these researchers have highlighted the degree of variability in coastal environments through time and space, meaning that simplistic notions of highly marginal vs highly productive are not easily applied.

Tied to these broader issues is the nature of mollusc exploitation; as noted by Erlandson (2001:293), no other class of marine resources has produced more discussion among archaeologists. Over the last century, archaeological depictions of molluscs have largely centred on them being a secondary,

marginal, or hardship resource, based on their small size and perception as time/energy inefficient resources, as well as relatively simplistic nutritional comparison with larger-bodied terrestrial species (see critiques in Erlandson, 2001:294; Erlandson and Fitzpatrick, 2006:6). The opposing argument is that molluscs require little technological investment and minimal search time, and via mass harvesting can provide reliable yields that, for example, can buffer economic risk (Braje and Erlandson, 2009; Jones, 1991; Erlandson, 2001:294). In fact, there are archaeological examples from around the world that would suggest a multitude of economic roles for molluscs, from fallback, supplementary and or buffering resources (e.g. Colonese et al., 2011) to integral economic components (e.g. Erlandson, 2001:331; Jerardino, 2010). Across much of eastern Africa, however, the notion of mollusc harvesting being linked to environmental deterioration, population pressure and resource stress (Msemwa, 1994) remains prevalent. The main issue with this position relates to the general paucity of archaeomalacological research available, largely due to different research priorities in the region, meaning that this dominant view requires systematic testing and cannot just be assumed.

Following Bailey (2004:46), who advocated for more detailed investigations of recent coastal archaeological records, marine resources and maritime activities (as recently synthesised for eastern Africa by Fleisher et al., 2015), here we present archaeomalacological analyses from Unguja Ukuu and Fukuchani, two late first millennium CE trading sites in the Zanzibar archipelago off the coast of Tanzania, eastern Africa (Figure 1). The aim here is to systematically explore the nature of past mollusc exploitation as an additional means of understanding human interactions with coastal environments, and to provide detailed baseline archaeological data from which further exploration of these issues can occur.

2. Previous Views on Mollusc Exploitation in Eastern Africa

The Swahili coast of eastern Africa extends from Somalia to Mozambique and includes offshore islands from the Lamu Archipelago to Pemba, Zanzibar, Mafia and the Comoros. It is well known for its role in the western Indian Ocean trading networks. The Swahili present a distinctive, coastal-oriented society, that developed from small-scale, farming and fishing communities, with increasing population sizes, maritime social and economic adaptations, maritime trade, and the development of mercantile urban centres by the second millennium (e.g. Fleisher et al., 2015). The settlements of Unguja Ukuu and Fukuchani both belong to the eastern African Middle Iron Age (MIA) or Early Tana Period, the latter taking its name from the distinctive Early Tana Tradition/Triangular Incised Ware (ETT/TIW) ceramics found at coastal sites between the 7th and 10th centuries CE (following the ETT/TIW chronology provided Horton and Chami, in press; Fleisher and Wynne-Jones, 2011:253). These wattle-and-daub mixed-farming settlements were linked to expanding Indian Ocean trade and early Islamisation, and are widely considered the precursor to Late Iron Age (or Swahili period, c. 11th to 15th centuries CE) stone towns characterised by an increasing maritime focus, Islamic practice, urbanisation, and the emergence of a merchant élite (Fleisher et al., 2015; Horton and Middleton, 2000).

Previous archaeological and ethnographic research on the eastern African coast and islands has highlighted the rich and productive nature of the intertidal and marine environment, with a diverse range of resources available for exploitation. Unsurprisingly, significant numbers of molluscs are often present in Iron Age archaeological deposits (e.g. Breen and Lane, 2003; Chami, 1994; Msemwa, 1994; Mudida and Horton, 1996). However, as noted by Mudida and Horton (1996:389), Fleisher (2003:354) and more recently Douglass (2016), there is limited information available for molluscs recovered from archaeological sites on the eastern African coast. In general, where molluscan assemblages have been reported, these data are often limited to provision of basic species lists or a focus on the limited range of dominant taxa, and recording of their relative abundance (largely via specimen counts and/or weight) (e.g. Juma, 2004; Radimilahy, 1998; Wilson and Omar, 1997; Wright, 1992; Wright et al., 1984). As such, there is little comparative data available from which to

contextualise the nature of mollusc exploitation across the region. The following discussion, therefore, highlights some of the more detailed considerations of molluscan assemblages rather than providing an exhaustive overview of all sites across the region. At the most basic level, these data indicate that, although there are several taxa that commonly occur in archaeological deposits as a part of the general suite of Indian Ocean species, there is a degree of variability in the overall range and abundance of taxa and habitat zones exploited.

Several sites from the Lamu Archipelago off the northern coast of Kenya provide some detail on the nature of the molluscan assemblages recovered and potentially the role of these resources within the coastal economy. Evidence from the large, dense urban 8th to 14th century settlement of Shanga (see Figure 1 for location of sites mentioned throughout) suggests a highly productive coastal and marine environment, including significant molluscan resources, although Mudida and Horton (1996:392) indicate that direct comparison with other economic resources is problematic due to the large amount of shell discarded relative to comparatively lower protein yield. At Shanga, 15 marine mollusc taxa were identified from 1208 specimens, including Cypraeidae (combining *Cypraea tigris*, *Monetaria annulus* and *M. moneta* at c. 55%), *Strombus* spp. (c. 15%), Potamididae (c. 7%), Fasciolariidae (c. 6%), *Murex* spp. (c. 6%), and minor amounts of Mactridae, *Nerita* spp., *Polinices* sp., *Pinctada imbricata*, *Oliva* spp., *Anadara* spp., *Cerithium* spp., *Chicoreus ramosus* and *Nautilus pompilius* (Mudida and Horton, 1996:389). There appears to be a degree of spatial and temporal variability in the deposition of molluscan remains at the site, with the bulk of the Trench 1 material recovered from the earliest occupation phases (c. 750 – 1000 CE), followed by a significant decline in abundance, although little variation was noted in the proportional contribution of the taxa identified through time (Mudida and Horton, 1996:392). This sequence is interpreted relative to the fish and other vertebrate fauna, where Mudida and Horton (1996:392) suggest that the rarity of these faunal components in the earlier levels is complemented by molluscs in "quantities sufficient to supplement the overall diet". From nearby Pate (late 8th–19th century CE), Wilson and Omar (1997) recorded a limited range of molluscan taxa from 2187 specimens, with the assemblage

overwhelmingly dominated by *Terebralia palustris* (c. 80%), followed by Cypraeidae (c. 10%) and *Strombus* spp. (c. 5%), with minor contributions from *Nerita* spp., *Cirsotrema* spp., *Fasciolaria* spp., *Cerithidea obtusa*, Cassidae, *C. ramosus* and *Murex* spp. In addition to noting low levels of deposition across all phases of occupation at the site, Wilson and Omar (1997:60) conclude that the molluscan assemblage conforms to the general perspective of these resources as "hardship food" for the Swahili.

The Middle Iron Age sites of Mpiji and Changwehela, north of Dar es Salaam on the Tanzanian coast, report a similar range of taxa, although the molluscan fauna from Changwehela is particularly small (n = 88) and predominantly comprised of *T. palustris*. Significantly larger molluscan assemblages were recovered from Mpiji, a 6th to 7th century site, with 17 molluscan taxonomic categories recorded and a total sample size of 6708 specimens (Chami, 1994:68; Msemwa, 1994:317). Here the Melongenidae dominate (c. 62%), followed by *T. palustris* (c. 32%), with small numbers of *Pleuroploca trapezium*, *Oliva* spp., *Anadara antiquata*, Cypraeidae, *C. ramosus*, *Nerita* spp., Naticidae, *Cypraecassis rufa*, *Pinctada* sp., *Strombus* sp., *Lambis lambis*, *Macoma* sp., *Donax* sp. and *Conus* spp. On Zanzibar, Kleppe (1995 cited in Fleisher, 2003:357) records significant mollusc deposits at the 12th century site of Kizimkazi Dimbani, largely from a partially excavated midden deposit. Seven taxa were identified from 7035 specimens, with 70% of the assemblage comprised of *T. palustris*, in addition to *Turbo marmoratus* (c. 9%), *Strombus* sp. (c. 8%), and small numbers of Cypraeidae, *L. lambis*, *Nerita* spp. and *Pleuroploca trapezium* (Fleisher, 2003:362). Finally, from Pemba Island, at the 9th century site of Kaliwa the most common taxa from the assemblage of 768 specimens were *Strombus* spp. (c. 64%), *Cerithium* spp. (c. 13%), *P. trapezium* (c. 7%) and *T. palustris* (c. 6%), with evidence for a decrease in deposition through time. Associated with this shift in density was a decrease in the frequency of the smaller *G. gibberulus* concomitant with an increase in the larger bodied *P. trapezium* and *C. ramosus* (Fleisher, 2003:358-359). Similar trends were seen at the Middle to Late Iron Age (8th to 14th century) site of Bandarikuu, with the assemblage of 108

specimens dominated by *P. trapezium* (c. 72%) and *T. palustris* (c. 27%), with lower densities after the 9th century seen to indicate a decreasing reliance on molluscan resources (Fleisher, 2003:361).

Perhaps the most influential research related to mollusc exploitation in eastern Africa is the pivotal ethnoarchaeological study undertaken by Msemwa (1994). Based on his research around Dar es Salaam, Msemwa (1994:295) argues that molluscs are predictable resources, and since large quantities can be collected in a short period, their exploitation reflects a risk minimising strategy used when fish or terrestrial game were not available in sufficient quantities. Mudida and Horton (1996:389) note similar contemporary behaviours on Zanzibar and Pemba, where molluscs are used as subsistence resources during periods of food shortage. Msemwa (1994:295) also argues against the position that molluscs are easily accessible (and therefore dependable) due to the limited amount of time in which these resources are accessible, in addition to this type of foraging behaviour being both hazardous and strenuous. Archaeologically, the implication of mollusc foraging as a risk-minimisation adaptation is that higher densities of shell will indicate communities under considerable protein stress (Msemwa, 1994:303). Building on this position, Fleisher (2003:354-355) states that "Shellfish gathering can be seen as an enterprise of last resort, turned to in times of need as well as a pursuit of lower class members of society. This is due primarily to the low protein yield of shellfish and the strenuous and hazardous nature of its procurement. … Thus in the context of complex societies, evidence for shellfish should indicate either times of resource stress, or economically disadvantaged populations."

In one of the most detailed considerations of the archaeological molluscan evidence from eastern Africa, Fleisher (2003:358) develops a series of testable propositions based on the position outlined above, including: an increase in mollusc exploitation during periods of subsistence stress in any given locale, and higher rates of exploitation in non-elite contexts (non-elite neighbourhoods in urban centres, rural villages). Drawing together the available archaeological data, Fleisher (2003:361) compares trends in species composition and shell density (both NISP and weight/m^3) drawn from several eastern African Iron Age sites, including Mpiji, Shanga, Kizimkazi Dimbani and Chwaka. He

notes a range of commonly exploited taxa although relative abundances vary (as highlighted above for these sites), with primary exploitation of the intertidal reef zone seen to reflect a highly opportunistic process of coastal foraging. The density of shell appears to diminish through time with an associated increase in fish and animal bone, particularly at Shanga and Chwaka. Shell densities are highest at Shanga from 800-1000 CE (23 NISP/m^3) and Chwaka from 1000-1300 CE (130 NISP/m^3), at both sites dropping significantly in the later phases (Shanga 1000-1400 CE = 9 NISP/m^3, Chwaka 1300-1500 CE = 18 NISP/m^3) (Fleisher, 2003:361, 363). Comparison between Kaliwa and Chwaka is used to highlight the differences between urban and rural mollusc exploitation. At Kaliwa, a small rural site, shell density is the highest of any site (240 NISP/m^3), except for the early deposits excavated at Mpiji (c. 300 NISP/m^3; Chami, 1994:68). These higher densities, especially compared to the larger urban settlement of Chwaka, would appear to confirm the expectation that mollusc exploitation was higher in non-elite/rural contexts (Fleisher, 2003:363; see also Christie, 2011).

Here we build on and critically evaluate this series of archaeological expectations for the sites of Unguja Ukuu and Fukuchani, incorporating not just an understanding of taxonomic composition and shell density, but also including analyses of habitat representation and assemblage richness and diversity.

3. Site Locations and Descriptions

Two Zanzibar sites, Unguja Ukuu and Fukuchani (Figure 1), were excavated in 2011 and 2012 by the Sealinks Project. These sites are some of the earliest known Iron Age settlements on the island, importantly containing evidence for early long-distance trade (Horton and Clark, 1985; Juma, 2004), and as such have been a key part of the Sealinks Project's investigation of eastern African maritime development and broader connectivity across the Indian Ocean. These two sites also provide a comparison between a more densely settled proto-urban community (Unguja Ukuu) and a smaller

wattle-and-daub trading village (Fukuchani) within which to evaluate the nature of economic molluscan exploitation as previously outlined.

3.1 Unguja Ukuu

The site of Unguja Ukuu, located on Menai Bay on the southwest coast of Zanzibar, is a large (up to 17 ha) and significant trading port and pre-stone architecture proto-urban centre (Figure 2). Five trenches were excavated at Unguja Ukuu (UU10-UU11, UU13-UU15; total area of 23m^2) by Sealinks personnel, four of these trenches (UU11, UU13-UU15; 19m^2) are analysed here. All trenches were excavated using the single-context method (defined stratigraphically as the unit of record following the Museum of London Archaeological Site Manual, 1994), with the invertebrate faunal material collected from 100% of all excavated deposits, either by dry sieving (3 mm mesh) during excavation, or through flotation (0.3 mm mesh) and wet sieving (1 mm mesh) of sediment sub-samples excavated from each context. Trenches UU11 and UU14 were located 3 m apart on a raised beach immediately adjacent to the shoreline of Menai Bay, about 10-20 m from the current high-water mark. These deposits were c. 3–3.3 m deep, and comprised a sequence of highly organic, culturally rich midden layers alternating in the lower part of the trench with layers of beach sand. This sequence likely reflects fluctuations in the intensity of use of this area of the site over time, possibly related to changes in sea level and/or beach transgression and regression events. UU13 and UU15, placed only a few meters apart in an area behind the boundary wall of the present-day hotel, produced shallower sequences (c. 1.4 m) and appear to be associated with a mixture of domestic and industrial activities, the latter indicated by the presence of a large (1.38 m diameter) lime-burning pit in UU13.

Both the previous (Horton, in press; Juma, 2004) and more recent (Sealinks) excavations have uncovered substantial midden deposits (containing vertebrate and invertebrate remains) associated with wattle-and-daub structures. A range of local and non-local trade wares, glass and shell beads,

bead grinders, iron slag and local ETT/TIW ceramics were also recovered, in addition to African and Asian crop remains (Crowther et al., 2016b; Horton, in press; Juma, 2004; Wood et al., 2016). The main period of occupation at Unguja Ukuu, determined via Bayesian analysis of 31 new AMS dates obtained by the Sealinks project, occurred in the 7th-10th centuries CE (Crowther et al., 2016b, in prep.). The stratigraphic sequence and available radiocarbon chronology for trench UU14 also provides an opportunity to investigate change through time in mollusc exploitation, with a lower (contexts 1446-1427; mid-7th to end-8th C CE / pre-800 CE) and an upper (contexts 1426-1400; 9th C CE + / post-800 CE) midden phase identified.

3.2 Fukuchani

Located on the northwest coast of Zanzibar, Fukuchani comprises approx. ten mounded middens (each up to 2 m high and 10 m long) situated parallel to the coast (Figure 3), although much of the site has been heavily disturbed since initial excavations in 1989 and 1991 (Horton, in press; Horton and Middleton, 2000). Three trenches were excavated at Fukuchani (FK10-FK12; total area 7m^2) by the Sealinks Project following the same methods noted above, with the molluscan assemblages from all three trenches incorporated into the analyses below. FK10/12 (the latter being an extension of the former, creating a single 1 x 5 m trench) was positioned in the central area of the site where it transected the remnants of a midden mound. Reaching a max. depth of 1.2 m, FK10/12 revealed midden deposits as well as the remains of a daub structure. FK11 was located on the margins of the site, closer to the coastline. This trench revealed a midden deposit overlying an *in situ* flexed human burial with a small cache of assorted marine shells placed around its neck and chest. At Fukuchani, ETT/TIW ceramics, glass and shell beads, and Near Eastern trade wares, were recovered. Like Unguja Ukuu, the agricultural component of subsistence appeared to focus on African crops such as sorghum, pearl millet, and baobab (Crowther et al., 2016b). Three AMS dates from FK10/12 as well as diagnostic ceramics provide evidence of occupation in the 7th-8th centuries CE.

3.3 Environmental Setting

Menai Bay is an expansive, shallow bay that offers a range of mollusc-bearing habitats immediately adjacent to the site of Unguja Ukuu. Currently, the marine environments of the bay are a mix of extensive, shallow algal flats dominated by *Halimeda*, seagrass beds comprised mainly of *Thalassia hemprichii* and *Cymodocea* spp., and seagrasses and patch reefs in deeper areas of the bay (Berkström et al., 2013:44). Dense mangrove forests have been present in Menai Bay likely from the early Holocene, with the configuration of mangrove cover fluctuating through time due to a combination of sea-level changes, climate, geomorphology and anthropogenic activity. However, mangrove habitats would have been present in the landscape throughout the occupation of Unguja Ukuu (Punwong et al., 2013). In contrast, marine habitats of northern Unguja, including those adjacent to Fukuchani, are characterised today by a relative lack of mangroves compared to the southern coast, and a greater abundance and coverage of fringing reefs and patch reefs (Richmond, 2014). Unlike the algal-dominated sand and mud flats adjacent to Unguja Ukuu, the marine habitats at Fukuchani feature sand flats and patch-reefs in greater abundances.

4. Methods

4.1 Taxonomic Identification, Relative Abundance and Taphonomy

The Unguja Ukuu and Fukuchani invertebrate assemblages were analysed at the House of Wonders Museum (Beit-el-Ajaib) in Stone Town, Zanzibar, in 2013 and 2015. As a physical comparative reference collection was unavailable, all material was identified to the lowest possible taxonomic level using published guides (Abbott, 1989; Abbott and Dance, 1998; Bequaert, 1951; Carpenter and Niem, 1998; Richmond, 2011; Robin, 2008, 2011; Rowson, 2007; Rowson et al., 2010; Spry, 1964, 1968). To avoid potential over-identification, those specimens that did not retain diagnostic features or morphological characteristics for species level attribution were assigned to the appropriate genus or family (e.g. Driver, 2011; Harris et al., 2015; Szabó, 2009:186; Woo et al., 2015:3). For consistency,

all taxonomic nomenclature has been standardised via reference to the World Register of Marine Species (WoRMS Editorial Board, 2016).

Each taxon was quantified via calculation of the Minimum Number of Individuals (MNI) for each individual context (representing discrete depositional events) and summed per trench or occupational/midden phase (e.g. trench UU14). As detailed in Harris et al. (2015), MNI was recorded using taxon-specific Non-Repetitive Elements (NRE). After siding bivalves, the NRE included the umbo and beak, the anterior and posterior portions of the hinge/dentition, and the anterior and posterior adductor muscle scars. The range of gastropod NRE included the spire, aperture, aperture lip, posterior and anterior canals, the umbilicus, the base and labum (Cypraeidae), the columellar deck (Neritidae), and calcified opercula (Turbinidae, Neritidae and Pomatiasidae). Following Giovas (2009), the Polyplacophora (chiton) MNI calculation was based on the highest counts of the apex of the anterior and mucro of the posterior valves. To minimise issues of interdependence (Lyman, 2008), MNI calculations per context were based on the NRE appropriate to the highest taxonomic level (family, genera or species) per context, ensuring that individuals were not counted multiple times.

The condition of the shell was noted for all contexts in a qualitative fashion, with the extent of dissolution, fragmentation and burning categorised as low (0-50%), moderate (50-75%) or high (75-100%). Additionally, if a specimen was juvenile or contained evidence of beachrolling, boring, or epibiont adhesions on the inner surfaces of the shell, this information was also recorded.

4.2 Sample Size, Nestedness, Richness and Diversity

The adequacy of sample size and assemblage representativeness are assessed here using cumulative species area curves and nestedness analyses (e.g. Lyman, 2008; Peacock et al., 2012; Wolverton et al., 2015). Plotting the number of taxa (NTAXA) as a measure of taxonomic richness with sample size (MNI) should indicate sampling to redundancy when no new taxa are added with increasing sample

size (Lyman, 2004, 2008). Nestedness indicates whether samples with differing taxonomic richness are subsets of each other, as faunal assemblages with low richness should nest compositionally within those with higher richness when drawn from the same community. Nestedness temperature values allow this relationship to be measured, where 100° represents no nestedness and 0° represents a perfectly nested set of samples (Ulrich et al., 2009; Wolverton et al., 2015:502).

Multiple measures of richness and heterogeneity (following Magurran, 1988, 2004) are used here to assess molluscan species diversity, richness and evenness within the Unguja Ukuu and Fukuchani assemblages. For these analyses, taxonomic units were grouped to the highest common level (e.g. family, genus) where appropriate, which although potentially results in lower resolution and lower overall species richness, as a conservative approach it ensures independence in taxonomic classification (Nagaoka, 2000:100). In addition to NTAXA to assess species richness, the Shannon index (*H*), Simpson's index (1-*D*) and Shannon's evenness (*E*) are used to investigate assemblage heterogeneity. All diversity indices were calculated using Palaeontological Statistics (PAST) version 3.13 (Hammer et al., 2001).

5. Results

5.1 Unguja Ukuu and Fukuchani Assemblage Characteristics

The assemblages recovered from Unguja Ukuu (Table S1) and Fukuchani (Table S2) have been attributed to a large number of taxonomic categories. From the four Unguja Ukuu trenches, a total MNI of 6329 with 134 invertebrate taxonomic categories were recorded. Of these, 63 have been attributed to species level (three terrestrial gastropods, 26 marine bivalves and 34 marine gastropods), 44 to genus level (one barnacle, one terrestrial gastropod, 16 marine bivalves and 26 marine gastropods) and 24 to family or subfamily level (12 marine bivalves and 12 marine gastropods). There are three categories at higher taxonomic levels, including the Decapoda (crab), Cirripedia (barnacle) and Polyplacophora (chiton). At Fukuchani, a total of 119 invertebrate

taxonomic categories have been recorded, representing an MNI of 2152 from the three trenches. 53 taxa are recorded to species level (nine terrestrial gastropods, 13 marine bivalves and 31 marine gastropods), 35 to genus level (three terrestrial gastropods, 13 marine bivalves and 19 marine gastropods) and 28 to family or subfamily level (one terrestrial gastropod, nine marine bivalves and 18 marine gastropods). As with the Unguja Ukuu assemblage, the Decapoda (crab), Cirripedia (barnacle) and Polyplacophora (chiton) represent the higher taxonomic level attributions.

The overall condition of the shell from both sites can be characterised by low levels of burning, a moderate degree of fragmentation, and moderate to high levels of dissolution and chemical degradation. The Unguja Ukuu and Fukuchani data in Tables S1 and S2 have been separated to reflect the occurrence of the economic and incidental taxa, with the latter defined as those likely to represent natural incorporations into the deposit (e.g. via fluvial movement) or as harvesting by-products rather than for economic purposes. Falling within this category are all very small individuals/taxa, small juvenile specimens, those individuals exhibiting evidence of predatory boring, water rolling, epibiont adhesions and hermit crab modifications, as well as the small terrestrial gastropods. The Crustacea (Cirripedia and Decapoda) are also included in this category due to their small size and/or ambiguity in identification due to high levels of fragmentation. The occurrence of incidental specimens varies by trench for each site, between 1.9 - 47.5% at Unguja Ukuu and 22.5 - 47.2% at Fukuchani, indicating differential processes of natural deposition (e.g. aeolian, fluvial) and/or differing harvesting (e.g. selective vs non-selective) and processing practices within and between each excavation area. Comparing site totals is perhaps more informative, with 41.2% (total MNI 887) incidental specimens at Fukuchani, contrasting with 18.3% (total 1161 MNI) at Unguja Ukuu. There are numerous possible explanations for this difference, given the larger scale and different structure of Unguja Ukuu compared to Fukuchani, there could be comparatively higher degree of natural deposition or disturbance at the latter site due to its smaller structure, exposing the deposits to aeolian and fluvial processes to a greater degree. Differences may have also existed in the nature of the foraging strategies implemented between the two sites, linked to variability in

habitat structure and those areas focussed on for mollusc harvesting, increasing the proportional representation of incidental taxa. Alternatively, the molluscs harvested at Unguja Ukuu may have been processed in a different location or offsite (sensu Bird and Bliege Bird, 1997; Bird et al., 2002), representing differential activity and disposal locations.

Here, economic taxa are defined broadly and inclusively, not assuming from the outset the edibility of a given species (Szabó, 2009: 186), or whether a taxon was of primary/preferred or secondary/supplementary importance, or even a starvation resource (Douglass, 2016:18; Szabó, 2009:188). Those species that may be seen as non-subsistence (e.g. for food or decoration) as opposed to those directly incorporated into the diet (e.g. Christie, 2011), are also not viewed separately in the following analyses as they are not necessarily mutually exclusive categories, and still represent near-shore foraging and the exploitation of certain habitat zones.

Excluding the incidental categories from further analysis results in an overall MNI of 5168 from 124 taxonomic categories for Unguja Ukuu, and an MNI of 1265 from 96 taxonomic categories for Fukuchani. The ten dominant economic taxa at Unguja Ukuu (Figure 4A) are *Anadara antiquata* (1198 MNI, 23.2%), *Arca ventricosa* (1082 MNI, 20.9%), *Pinctada* spp. (591 MNI, 11.4%), *Atactodea striata* (229 MNI, 4.4%), *Monetaria annulus* (227 MNI, 4.4%), *Cypraea* spp. (195 MNI, 3.8%), *Terebralia palustris* (171 MNI, 5.5%), *Pleuroploca trapezium* (105 MNI, 2.0%), *Loripes clausus* (101 MNI, 2.0%) and *Lambis lambis* (77 MNI, 1.5%). Together these taxa comprise 76.4% of the total economic species at Unguja Ukuu, with 13 sub-dominant taxa (Figure 4B) that individually contribute ≤ 1.5% by MNI providing an additional 12.3% (637 MNI) combined. For Fukuchani, the ten dominant economic taxa represent 74.4% of the total assemblage by MNI (Figure 5A), including *Pinctada* spp. (475 MNI, 37.5%), Ostreidae (152 MNI, 12.0%), *Atactodea striata* (80 MNI, 6.3%), *Saccostrea cucullata* (50 MNI, 4.0%), *Lunella coronata* (45 MNI, 3.6%), *Arca ventricosa* (38 MNI, 3.0%), *Anadara antiquata* (31 MNI, 2.5%), the terrestrial *Achatina* spp. (25 MNI, 2.0%), *Nerita balteata* (24 MNI, 1.9%) and *Monetaria annulus* (21 MNI, 1.7%). The 13 sub-dominant taxa (Figure 5B) at Fukuchani again individually contribute ≤ 1.5% by MNI, and combined provide an additional 11.6% (147 MNI).

While there are similarities in the taxa exploited in each site, the differential contribution of some of the dominant and sub-dominant taxa likely reflect the structure of the coastline and marine habitat distribution in each location (as previously noted by Fleisher, 2003:361).

The relative abundance of taxa assigned to a range of habitat categories was investigated for all trenches at Unguja Ukuu (Figure 6A) and Fukuchani (Figure 6B). Two habitats dominate at Unguja Ukuu: intertidal/shallow subtidal reef/rock and intertidal/shallow subtidal sand/mud. For UU11, UU14, and UU15, these two habitats alone account for between 75.9% and 89.3% of MNI. Results from UU13 were anomalous, however, with only 39.6% of MNI derived from these habitats, but 56.3 % of MNI derived from subtidal reef/rock due to the dominance of *Pinctada* spp. in this trench. This pattern is similar to all trenches at Fukuchani, where subtidal reef/rock accounts for an average of 42% due to the prevalence of *Pinctada* spp. at this site. Other major habitats were consistent with results from Unguja Ukuu, with intertidal/shallow subtidal reef/rock and sand/mud accounting for between 35.1% and 55% at Fukuchani. A range of other habitats was represented at both sites, although the contribution of these habitats was minimal overall. Habitat representation at each site was broadly similar. Variation between Unguja Ukuu and Fukuchani habitat representation likely reflects the configuration of intertidal environments adjacent to the site, with Unguja Ukuu relatively dominated by sand and mud flats and mangroves, and Fukuchani featuring greater abundances of coral and rock habitats, but fewer mangroves and mud flats (Berkström et al., 2013; Richmond, 2014; Punwong et al., 2013).

5.2 Assemblage Structure, Richness and Diversity

Using data drawn from each context for the nestedness analyses (Tables S3-5) and construction of species area curves (Figure 7), rather than for each trench in total, allows for a more detailed investigation of overall assemblage representativeness and the identification of any potential outliers in the dataset. Based on the economic taxonomic categories combined to the highest

common level, nestedness analyses indicate highly nested assemblages for Unguja Ukuu (Table S3) and Fukuchani (Table S4), with low temperature values of 10.3° and 11.7° respectively, showing that for each site the sample has been drawn from the same community. For Fukuchani, this includes the shell material recovered in association with the human burial in trench FK11 (context 010), which at least in terms of taxonomic composition indicates no clear difference between that context and the overlying midden deposit (although potentially representing non-subsistence procurement). Cumulative species area curves, constructed by drawing on the data presented in Tables S3-S5 and plotting richness (NTAXA) against sample size (MNI) per context for both sites (Figure 7), display curves that have almost become asymptotic, with only a minor increase in richness over the last two to three data points indicating that these samples have virtually reached redundancy, and that additional samples would have a negligible effect on assemblage richness.

Richness and diversity has been calculated here for each individual trench in total (i.e. combining the data from each context) for both sites (Table 1). There are some differences in these measures across the trenches analysed, with higher NTAXA values for trenches UU14 and FK11, and lower NTAXA in UU11, indicating greater and lesser assemblage richness respectively. Simpson's Index (1-*D*) results are relatively consistent across both sites in presenting moderate to high evenness (ranging between 0.631 and 0.816). Both the Shannon Index (*H*) and Shannon Evenness (*E*) results display trends across these trenches that parallel that seen in the Simpson's Index, again indicating a moderate degree of diversity and evenness across these samples, except for UU13 and UU14, which display comparatively lower diversity and evenness. This is due to the higher abundance of the Pteriidae in UU13 and Arcidae in UU14 as the dominant taxa. The decrease in the diversity index values in these trenches, however, is relatively minor, but still highlights differential mollusc exploitation and spatial patterns of shell discard within the same site.

Descriptive statistics for the diversity indices for Unguja Ukuu and Fukuchani (Table 2) highlights some subtle differences in richness and diversity between these two sites, with consistently lower median values recorded from Unguja Ukuu. Mann-Whitney U tests are used here to investigate

whether the differences observed in the central tendencies are significant. These tests indicate that for NTAXA (U = 4.5, z = -0.357, p = 0.714, r = -0.13), Simpson's Index (U = 2.0, z = -1.237, p = 0.229, r = -0.47), Shannon Index (U = 3.0, z = -0.884, p = 0.4, r = -0.33) and Shannon Evenness (U = 5.0, z = -0.177, p = 0.857, r = -0.07), the median index values as reported in Table 4 are not significantly different. Both sites, therefore, provide some evidence for similar foraging strategies based on the richness and diversity values, where broadly they can be seen to exhibit a broad-based foraging strategy with minor emphasis (or selectivity) on a small range of species.

5.3 Shell Density

Shell density has been calculated in a similar way to that outlined above for the richness and diversity analyses, combining the relative abundance data from each context and deriving density estimates for each individual trench in total. Excavation volumes are available from the four Unguja Ukuu trenches, and from two of the three Fukuchani trenches (excluding trench FK11 as context volumes are currently not available). Shell density (MNI/m^3) has been calculated for each trench in total, in addition to density based on shell-bearing contexts only (Table 3). These data highlight spatial variability in shell density, particularly at Unguja Ukuu, where density ranges from 29 to 403 individuals per m^3 for the trench totals, and 36 to 508 individuals per m^3 for shell bearing contexts. The differences at Fukuchani are less marked, particularly when comparing the shell-bearing contexts only, however this is unsurprising given that FK12 is an extension of FK10, and therefore does not highlight spatial variability to the same degree as seen at Unguja Ukuu.

To compare the two sites, descriptive statistics for shell density are presented in Table 4, which shows slightly higher median density values at Unguja Ukuu (albeit to a less degree from the shell-bearing contexts alone). Mann-Whitney U tests indicate that median densities from the total excavated deposit (U = 3.0, z = -0.231, p = 0.8, r = -0.09) and densities from shell-bearing contexts (U = 4.0, z = 0.231, p = 1, r = 0.09) as reported in Table 4 for Unguja Ukuu and Fukuchani are not

significantly different. The similarities in shell density, which can be seen as a measure of the intensity of shell exploitation and discard, would suggest that molluscs were filling broadly similar roles within the economies of the people occupying these sites, particularly in combination with the richness and diversity data presented above.

5.4 Diachronic Trends

The stratigraphic sequence identified for trench UU14 from Unguja Ukuu enables a broad analysis of change through time to be undertaken, with the assemblage divided into lower (mid-7th to end-8th C CE / pre-800 CE) and upper (9th C CE + / post-800 CE) midden phases. Nestedness analyses (Table S5) indicate highly nested assemblages for both phases, with low Nestedness temperature values of 16.1^{o} for the lower and 12.1^{o} for the upper midden. Cumulative species area curves for both phases (Figure 8) are broadly like those generated for the sites in total, with the upper midden curve indicating sampling to redundancy for the more recent phase. The lower midden cumulative species area curve does not asymptote, although given the smaller sample sizes and restricted number of taxa in comparison with the upper midden, this may well reflect a difference in foraging behaviour rather than a sampling issue. Given the conservative approach to structuring the taxonomic categories for these analyses, any increase in sample size would be likely to have a minimal effect on NTAXA (particularly as the curve flattens over the largest three sample size data points).

The 16 dominant economic categories from both midden phases are graphed in Figure 9, rank ordered by %MNI for the lower midden to highlight proportional shifts through time. These taxa comprise 94.8% of the lower midden (329 MNI) and 95.1% of the upper midden (3173 MNI), with the remaining approx. 5% by MNI represented by nine and 23 taxonomic categories for the lower and upper midden phases respectively. The differences in rank order between the midden phases are relatively subtle, with the Arcidae and Cypraeidae maintaining assemblage dominance through time and increasing by 9% and 6% respectively into the upper midden. All other taxonomic

categories exhibit minor shifts in rank order, the Potamididae and *Gafrarium* spp. increase slightly (albeit at <1%), with the other taxa exhibiting a slight decrease (at an average of 1.5%).

A diachronic analysis of UU14 was conducted for upper and lower midden phases. The assemblage from UU14 was derived from two main habitats across both phases, intertidal/shallow subtidal reef/rock and intertidal/shallow subtidal sand/mud (Figure 10). In the lower phase, intertidal shallow/subtidal sand/mud habitats account for 51% MNI, with an increase to 58.5% in the upper phase, with a concurrent minor decrease in intertidal/shallow subtidal reef/rock from 27.2% to 24.6%. A decrease in the relative abundance of taxa from other habitats was also noted between lower and upper phases, with other habitat categories contributing 21.8% MNI in the lower phase, and 16.9 % MNI in the upper phase. Within these non-dominant habitats, slight increase in the relative abundance of the supratidal rock/mangrove habitat (5.4% MNI lower, 7% MNI upper) was reported between upper and lower phases. Conversely, minor decreases were noted for forest woodland/forest litter (5.1% MNI lower, 3.1% MNI upper), subtidal reef/rock (5.1% MNI lower, 3.5% MNI upper), and intertidal rock/mangrove, which decreases from 1.9% MNI in the lower phase, and is not present in the upper phase.

Richness and diversity, calculated for the shell-bearing contexts from both phases (Table 5; Figures 11A-D), further emphasise the differences in assemblage composition noted above. There is an increase in assemblage richness from the lower (*Mdn* = 7) into the upper (*Mdn* = 19) midden phase, a difference that is significant based on a Mann-Whitney U test (U = 34.0, z = -2.254, p = 0.021, r = -0.45). Assemblage diversity measured by the Shannon index (H) is relatively low for both phases, and exhibits a slight increase through time (lower *Mdn* = 1.804; upper *Mdn* = 1.977) in line with increasing richness, although this difference is not significant (U = 68.5, z = -0.333, p = 0.733, r = -0.07). In contrast, both measures of evenness display moderate to high values, with a decrease in evenness from the lower into the upper midden phase, likely reflecting a combination of increased richness and increasing proportional abundance of the Arcidae and Cypraeidae as the dominant taxa. Although demonstrating a slight decrease, the difference in the median Simpson's index values

are not significant (U = 42.0, z = -1.806, p = 0.070, r = -0.36), contrasting with the decrease in evenness through time exhibited by the median values obtained for Shannon's Evenness which are highly significant (U = 25.0, z = -2.764, p = 0.004, r = -0.55). Together, these data indicate an increase in the number of taxa exploited through time with an increased focus on a small number of key species, which suggests both broad-based foraging and increasing selectivity as non-mutually exclusive foraging strategies.

Total shell density falls within the ranges established above, with 105/m^3 for the lower midden and 332/m^3 for the upper midden. Shell density calculated per context demonstrates a high degree of variability within and between these midden phases (Figure 12A), with several significant peaks in shell discard occurring through the upper midden, followed by a decrease to similar levels exhibited within the lower phase. That said, the increase in total phase density through time is further emphasised by the descriptive statistics (Table 6) and boxplots for the lower and upper middens (Figure 12B). As expected based on the nature of these data, shell density from the lower midden (Mdn = 89) and upper midden (Mdn = 400) is significantly different (U = 31.0, z = -2.413, p = 0.014, r = -0.48).

6. Discussion and Conclusion

6.1 Issues of Scale and Resolution: Analogy, Analyses and Interpretation

There are several issues that bear discussion at the outset in reviewing the analyses above relative to the nature of previous interpretations of archaeological molluscan assemblages in eastern Africa. These issues specifically relate to the level of detailed archaeomalacological analyses, the scale and resolution of both the archaeological and ethnographic data, and the use of modern analogies that relate specifically to the interpretation of past invertebrate foraging behaviours. There has been considerable emphasis placed on the coastal adaptations and maritime orientation of the Swahili (Fleisher et al., 2015; Horton, in press), with additional interest focused on the productive nature of

coastal and marine environments across the region, and their relationship to a local reliance on molluscan resources (e.g. Breen and Lane, 2003; Horton, in press; Juma, 1994). As noted above, however, there has been a comparative lack of highly detailed, specialist analyses of archaeomalacological assemblages across the broader region, and interpretations of archaeological shell assemblages have been heavily influenced by modern observations of mollusc foraging (see for example Msemwa, 1994; Mudida and Horton, 1996; Wilson and Omar, 1997).

In many respects, the way analogies have been used specifically regarding mollusc harvesting has conflated the imminent (unchanging processes) and configurational (historically contingent) properties (sensu Wolverton and Lyman, 2000). In this case, largely due to the lack of detailed archaeological analyses to form a coherent basis for assessing the robusticity of the analogical argument (following Currie, 2016; Wylie, 1985), there appears to be an assumption of continuity in behaviour through time and space via a direct historical approach (similar to Huffman, 2001, see Lane, 2005 for further discussion). This is problematic due to issues of scale and resolution between the archaeological and modern datasets, particularly where the data have been obtained from very different social and economic circumstances (as highlighted recently by Ichumbaki, 2014:2, for Tanzania; see also Faulkner, 2013; Jerardino, 2010, 2012).

This combination of direct analogical reasoning, coarse scale and low resolution in the archaeological data has potentially reinforced the notion of the secondary importance of these resources. Combined with early ideas of molluscs being low rank and hardship resources common in the international archaeological literature (e.g. Cohen, 1977; Osborn, 1977), this situation may in part explain the general lack of detailed archaeomalacological analyses in eastern Africa (see Colonese et al., 2011 for a broadly similar argument for the Mediterranean). Therefore, to understand the degree of similarity and difference in human foraging behaviour between the past and the present, and particularly within highly dynamic coastal and marine environments, the appropriate scale and resolution in archaeological analyses are required.

Focussing on the two main data elements of taxonomic composition and shell density used previously to assess the relative contribution of molluscs to the economy, there are clear differences in data structure between the Fukuchani and Unguja Ukuu assemblages and those previously reported in the region. The total number of molluscan taxa from the previously studied sites summarised in Section 2 range from three to 17, and in comparison, 134 taxonomic categories (43 independent taxa) from Unguja Ukuu and 119 taxonomic categories (41 independent taxa) from Fukuchani have been recorded. It is likely that these differences in assemblage richness and composition between Unguja Ukuu and Fukuchani, and other sites across the region, relate to the nature of the recovery and analytical methods being implemented. While earlier research provides important initial data on the dominant taxa recovered, and highlights similarities relating to the exploitation of certain species, how assemblages have been sampled and the level of detail in their analyses can affect our understanding of assemblage composition, richness and diversity, and ultimately how people structured their foraging activities. Similarly, shell density ranges from <1/m^3 at Shanga to c. 347/m^3 at Mpiji (Fleisher, 2003:364), with total trench densities at Unguja Ukuu ranging from 29/m^3 to 403/m^3 (*Mdn* = 181.5), and at Fukuchani between 92/m^3 and 159/m^3 (*Mdn* = 201.5). While appearing to conform to the broader density range, the assemblages at Unguja Ukuu and Fukuchani have been analysed differently compared to those from other sites in the region, with density values being based on MNI for Unguja Ukuu and Fukuchani, and on NISP for the previously studied sites in the region.

The density values reported in the present analyses do not therefore represent the total mass of recovered shell, however in addressing the issue of differential mollusc exploitation through time, basing density estimates on the minimum number of individuals (broadly identified as economic) rather than the maximum number of fragments or maximum weight of shell is more appropriate. The argument that MNI often better represents the size and structure of molluscan assemblages is relevant here, given the potential for differential fragmentation and shell weight loss within and between taxonomic categories (due to morphology, robusticity, size and the micro-structural

properties of the shell) resulting from a combination of anthropogenic (processing) and natural (compaction, burning, dissolution) factors that can skew analyses of shell density. Together, these differences in taxonomic composition, understanding and consideration of taphonomic processes, and shell density relate to issues of scale and resolution in the datasets and modes of analysis, possibly reflecting differences in research priorities, sampling and recovery, and implementation of higher resolution identification and analytical methods. These factors together make a direct comparison between Unguja Ukuu, Fukuchani and other eastern African sites particularly difficult. The coarse structure of previous archaeomalacological datasets creates some issues in terms of clearly identifying similarities and differences across assemblages, with a tendency for homogenisation at lower resolution, particularly in comparison with modern data obtained via different scales of observation (e.g. short duration ethnographic vs the longer term, palimpsest archaeological record).

6.2 Similarities and Differences in Mollusc Exploitation on Zanzibar

At a broad level, and despite clear sample size differences, the Unguja Ukuu and Fukuchani assemblages appear to be quite similar in many respects. The range of dominant taxa overlap to a considerable degree between the two sites, although there is a high degree of variability in terms of proportional representation and rank order of these taxa. This variability is linked to differing levels of exploitation in available intertidal reef, rock and sand/mud habitats at Unguja Ukuu compared with a higher representation of subtidal reef and rock species exploitation at Fukuchani, likely reflecting the configuration of local intertidal habitats at each site. Further to this, and connected to the point raised in Section 5.2 concerning the proportional abundance of incidental taxa and variability between the two assemblages, differential foraging strategies associated with habitat configuration is likely to be a contributing factor. Foraging in near-shore rocky and coral niches would potentially increase the collection of incidental taxa relative to economic species, largely as a

product of a reef sweeping collection strategy (e.g. Harris and Weisler, 2017:19; Szabó, 2009:208). Within coral and rock habitats there is generally an increased degree of taxonomic richness with substratum rugosity (e.g. Gatwicke and Speight, 2005; Kohn and Leviten, 1976), and the diversity analyses support this interpretation to a degree, with comparatively lower median values for richness and diversity linked to the dominant mudflat and mangrove environments at Unguja Ukuu. At this analytical level, these data reinforce to a degree the range of taxa noted from previous research across the region, as well as conforming to recognised trends in geographic variability in taxonomic composition linked to location-specific environmental structures (e.g. Fleisher, 2003:361).

As noted above, the similarities in shell density for these two sites in total, where this measure serves as a proxy for the intensity of mollusc foraging, also suggests a comparable level of exploitation of these resources. With very similar richness, diversity and evenness for both sites in total, all falling within a moderate to moderate/high range for each index, similar foraging strategies would appear to be in operation at this broad comparative level. While some taxa are clearly more abundant, overall these assemblages are very rich (for this region) and relatively even in their overall composition, with some species being selected at higher rates within an overall strategy that may be characterised as being less selective or discriminatory. In this regard, Unguja Ukuu and Fukuchani would appear not to conform to the expectation of increased emphasis on molluscs in rural villages as opposed to more urban or elite contexts (Christie, 2011; Fleisher, 2003). This may reflect the nature of Unguja Ukuu's trading settlement – perhaps it was not an urbanised, elite site in the traditional sense, but more of a gathering of local producers and traders not that differentiated socially or economically from others on the island – or it could reflect just the part of this very large site that was sampled.

Change through time based on trench UU14 at Unguja Ukuu indicates a significant increase in species richness, coupled with a minor increase in diversity (albeit remaining comparatively low) and a significant decrease in assemblage evenness. The range of dominant taxa remain consistent between the earlier and later midden phases, although there is a proportional increase in the later

midden in the Arcidae and Cypraeidae, with a minor increase in the exploitation of near-shore sand and mud habitats and minor decrease in taxa obtained from intertidal reef and rocky niches. Importantly, shell density increases significantly from the lower midden into the upper midden phase, perhaps indicating a greater intensity of exploitation in the 8th-9th C CE compared with the earlier 7th-8th C CE, though this interpretation must be forwarded cautiously given that only a minimal spatial area of the site was sampled. The data presented by Fleisher (2003:364) on change through time in shell density at Shanga and Chwaka indicates a reduction at both sites, although these changes occur within the second millennium CE, whereas the Unguja Ukuu trends reflect occupation within the first millennium CE.

The Unguja Ukuu and Fukuchani vertebrate faunal assemblages are reported on in detail elsewhere (Prendergast et al., 2017), and in general both sites are characterised by high frequencies of fish (particularly reef and estuarine species), low to moderate numbers of domesticates, and a narrow wild assemblage dominated by a small number of woodland taxa (small bovids, bushpig and monkeys). At Unguja Ukuu, wild taxa are comparatively less abundant, with a large proportion of caprines, and diachronically there was an increase in the abundance of Galliformes and emperor fish in the post-800 CE phase. Fish are proportionally less important at Fukuchani in comparison. These are important trends relative to the molluscan assemblages analysed here, where, following broader comparative analyses, Prendergast et al. (2017) note that the faunal evidence for the MIA Swahili coast largely reflects small-scale societies economically focussed on fishing, hunting or trapping, and foraging in equal or greater importance to farming and herding. Rather than being a fallback, secondary resource only exploited in times of protein or resource stress, molluscs can therefore be seen as another component of a broad-based economic strategy that appears to have been widely pursued along the Swahili coast by diverse-sized communities (see Ichumbaki, 2014:15-16 for a similar argument developed for the southern Tanzanian coast).

Resource stress would also not explain the increasing levels of molluscan exploitation through time at Unguja Ukuu relative to the broader faunal data. An interesting point raised by Msemwa

(1994:235-236) connected to risk minimising behaviour of mollusc collectors is increasing the range of species harvested in addition to an increase in the exploitation of a limited number of preferred taxa. He refers to this as opportunity maximisation linked to both the availability and demand for molluscan resources depending on the tidal periods, for example broadening the range of taxa collected during neap tides to minimise risk and maximising harvest of key species during spring tides. This would fall in line with the combination of selective and broad based foraging noted for the upper midden phase of UU14. Again, what this would suggest is that molluscs are not hardship resources in this context, but rather are key economic components used to buffer populations against economic risk. As noted above, rather than stress induced via a reduction in other sources of protein, the underlying mechanism in operation at Unguja Ukuu may relate to increasing population levels. Juma (2004:148-152) provides estimated increases in both site area and population size at Unguja Ukuu post-800 CE, shifting from 4ha to 17ha with an associated change in the adult population size from approximately 1600 to 4900. These changes correspond with the major Abbasid trade period (Juma 2004:25), providing the mechanism for expanding site and population size, including large numbers of foreign merchants on a seasonal basis. Similar trends have been recognised (albeit in different socio-economic contexts) in other regions worldwide where molluscs served as key low-cost, high-return buffering resources (e.g. Colonese et al., 2011; Jerardino, 2010; Stiner et al., 2000).

6.3 Conclusion

The data and interpretations presented here do not necessarily invalidate some of the general principles or expectations of the model developed by Fleisher (2003). Given the recent arguments proposed for increasing Swahili maritimity, social stratification and intensifying overseas trade during the second millennium CE (Fleisher et al., 2015), it is possible that the nature of mollusc exploitation and the role these resources played economically would have shifted significantly

during that period. As Unguja Ukuu and Fukuchani fall within the MIA (mid-late first millennium CE), assessing increasing socio-economic and status differentiation in the use of mollusc resources is not possible. The trends observed here are site and location-specific, but indicate the potential for significant variation in economic structure across the eastern African coastal region through time and geographically, in a similar fashion to that seen with the transition from the Early to Mid-Iron Age deposits at Juani in the Mafia Archipelago (Crowther et al., 2016a). What these data do provide, however, is a baseline understanding of the complexity of the molluscan assemblages in eastern Africa, and a means to further explore some of the issues highlighted here across the broader region (e.g. Crowther et al., 2016a; Douglass, 2016).

It is unlikely that the role of molluscs in past economic structures in eastern Africa would follow a single pattern through time and space; instead, we would expect it to be characterised by a high degree of variability, much like we see in the rest of the world. In the same way that we cannot assume that small bodied resources like molluscs were always low ranked, supplementary resources, neither can we assume that they were economically highly important within any given context. To be able to disentangle the complexities of these issues, and following the recent conclusions of Douglass (2016) in Madagascar (and more broadly Bailey, 2004:46), we need to emphasise detailed archaeomalacological analyses in eastern Africa as one research priority if we are to better understand the nature and degree of variability in human interactions with coastal and marine environments.

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References

Abbott, R.T., 1989. Compendium of Landshells: A color guide to more than 2,000 of the world's terrestrial shells. American Malacologists, Melbourne.

Abbott, R.T., Dance, S.P., 1998. Compendium of Seashells: A color guide to more than 4,200 of the world's marine shells. Odyssey Publishers, El Cajon, California.

Bailey, G., 2004. World prehistory from the margins: The role of coastlines in human evolution. Journal of Interdisciplinary Studies in History and Archaeology 1(1), 39-50.

Berkström, C., Lindborg, R., Thyresson, M., Gullström, M., 2013. Assessing connectivity in a tropical embayment: Fish migrations and seascape ecology. Biological Conservation 166, 43-53.

Bequaert, J.C., 1951. Studies in the Achatininae, a group of African land snails. Bulletin of the Museum of Comparative Zoology at Harvard College 105(1), 1-216.

Bird, D.W., Bird, R.L.B., 1997. Contemporary shellfish gathering strategies among the Meriam of the Torres Strait Islands, Australia: Testing predictions of a central place foraging model. Journal of Archaeological Science 24(1): 39-63.

Bird, D.W., Richardson, J.L., Veth, P.M., Barham, A.J., 2002. Explaining shellfish variability in middens on the Meriam Islands, Torres Strait, Australia. Journal of Archaeological Science 29(5): 457-469.

Braje, T.J., Erlandson, J.M., 2009. Mollusks and mass harvesting in the Middle Holocene: Prey size and resource ranking on San Miguel Island, Alta California. California Archaeology 1(2), 269-290.

Breen, C., Lane, P.J., 2003. Archaeological approaches to East Africa's changing seascapes. World Archaeology 35(3), 467-489.

Carpenter, K.E., Niem, V.H., (Eds.). 1998. The living marine resources of the western central Pacific: Volume 1. Seaweeds, corals, bivalves and gastropods. FAO Species Identification Guide for Fishery Purposes, Food and Agriculture Organization of the United Nations, Rome.

Chami, F.A., 1994. The Tanzanian Coast in the First Millennium AD: An archaeology of the iron-working, farming communities. Studies in African Archaeology 7. Societas Archaeologica Upsaliensis, Uppsala University, Uppsala.

Christie, A.C., 2011. Exploring the social context of maritime exploitation in the Mafia Archipelago, Tanzania: An archaeological perspective. PhD Thesis (University of York).

Cohen, M.N., 1977. The food crisis in prehistory: Overpopulation and the origin of agriculture. Yale University Press, New Haven.

Colonese, A.C., Mannino, M.A., Bar-Yosef Mayer, D.E., Fa, D.A., Finlayson, J.C., Lubell, D., Stiner, M.C., 2011. Marine mollusc exploitation in Mediterranean prehistory: An overview. Quaternary International 239(1-2), 86-103.

Crowther, A., Veall, M.A.., Boivin, N., Horton, M.C., Kotarba-Morley, A., Fuller, D.Q., Fenn, T., Haji, O., Matheson, C., 2015. Use of Zanzibar copal (Hymanaea verrucosa Gaertn.) as incense at Unguja Ukuu, Tanzania in the 7-8th century CE: Chemical insights into trade and Indian Ocean interactions. Journal of Archaeological Science 53, 374–390.

Crowther, A., Faulkner, P., Prendergast, M.E., Quintana Morales, E.M., Horton, M., Wilmsen, E., Kotarba-Morley, A.M., Christie, A., Petek, N., Tibesasa, R., Douka, K., Picornell-Gelabert, L., Carah, X., Boivin, N., 2016a. Coastal subsistence, maritime trade, and the colonization of small offshore islands in Eastern African prehistory. Journal of Island and Coastal Archaeology 11(2), 211–237.

Crowther, A., Lucas, L., Helm, R., Horton, M.C., Shipton, C., Wright, H.T., Walshaw, S., Pawlowicz, M.C., Radimilahy, C., Douka, K., Picornell-Gelabert, L., Fuller, D.Q., Boivin, N., 2016b. Ancient crops

provide first archaeological signature of the westward Austronesian expansion. Proceedings of the National Academy of Sciences of the United States of America 13 (24), 6635-6640.

Currie, A., 2016. Ethnographic analogy, the comparative method, and archaeological special pleading. Studies in History and Philosophy of Science Part A 55, 84-94.

Douglass, K., 2016. The diversity of Late Holocene shellfish exploitation in Velondriake, Southwest Madagascar. The Journal of Island and Coastal Archaeology, DOI: 10.1080/15564894.2016.1216480.

Driver, J.C., 2011. Identification, classification and zooarchaeology. Ethnobiology letters 2, 19-39.

Erlandson, J.M., 1994. Early Hunter-Gatherers of the California Coast. Plenum Press, New York.

Erlandson, J.M., 2001. The archaeology of aquatic adaptations: Paradigms for a new millennium. Journal of Archaeological Research 9(4), 287–350.

Erlandson, J.M., Fitzpatrick, S.M., 2006. Oceans, islands, and coasts: Current perspectives on the role of the sea in human prehistory. The Journal of Island and Coastal Archaeology 1(1), 5-32.

Faulkner, P., 2013. Life on the margins: An archaeological investigation of Late Holocene economic variability, Blue Mud Bay, Northern Australia. ANU Press, Canberra.

Fleisher, J.B., 2003. Viewing stonetowns from the countryside: An archaeological approach to Swahili regional systems, AD 800-1500. PhD Thesis (University of Virginia).

Fleisher, J. and Wynne-Jones, S., 2011. Ceramics and the early Swahili: Deconstructing the early Tana tradition. African Archaeological Review 28(4), 245-278.

Fleisher, J., Lane, P., LaViolette, A., Horton, M.C., Pollard, E., Quintana Morales, E., Vernet, T., Christie, A.C., Wynne-Jones, S., 2015. When did the Swahili become maritime? American Anthropologist 117, 100–115.

Giovas, C.M., 2009. The shell game: Analytic problems in archaeological mollusc quantification. Journal of Archaeological Science 36, 1557-1564.

Gratwicke, B., Speight, M., 2005. The relationship between fish species richness, abundance and habitat complexity in a range of shallow tropical marine habitats. Journal of Fish Biology 66(3), 650-66.

Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: Paleontological Statistics software package for education and data analysis. Palaeontologia Electronica 4(1).

Harris, M., Weisler, M., 2017. Intertidal Foraging on Atolls: Prehistoric Forager Decision-Making at Ebon Atoll, Marshall Islands. The Journal of Island and Coastal Archaeology 12(2), 200-223.

Harris, M., Weisler, M., Faulkner, P., 2015. A refined protocol for calculating MNI in archaeological molluscan shell assemblages: A Marshall Islands case study. Journal of Archaeological Science 57, 168-179.

Horton, M.C., in press. Zanzibar and Pemba: The archaeology of an Indian Ocean trading village. Ashgate, London.

Horton, M., Chami, F., in press. Swahili Origins. In: La Violette, A., Wynne-Jones, S. (Ed.) Swahili World. Routledge.

Horton, M.C., Clark, C.M., 1985. Archaeological survey of Zanzibar. Azania: Archaeological Research in Africa 20(1), 167-171.

Horton, M.C., Middleton, J., 2000. The Swahli: The social landscape of a mercantile society. Blackwell, Oxford.

Huffman, T.N. 2001. The Central Cattle Pattern and interpreting the past. Southern African Humanities 13(1), 19-35.

Ichumbaki, E.B., 2014. Archaeological and Ethnographic Evidence for the Historic Consumption of Fish and Shellfish along the Coast of East Africa in Tanzania. Journal of Indian Ocean Archaeology 10, 1-18.

Jerardino, A., 2010. Large shell middens in Lamberts Bay, South Africa: A case of hunter-gatherer resource intensification. Journal of Archaeological Science 37, 2291-2302.

Jerardino, A., 2012. Large shell middens and hunter-gatherer resource intensification along the West Coast of South Africa: The Elands Bay case study. The Journal of Island and Coastal Archaeology 7, 76-101.

Jones, T.L., 1991. Marine resource value and the priority of coastal settlement: A California perspective. American Antiquity 56, 419-443.

Juma, A., 2004. Unguja Ukuu on Zanzibar: An archaeological study of early urbanism. Studies in Global Archaeology 3. Societas Archaeologica Upsaliensis, Uppsala University, Uppsala.

Kohn, A.J., Leviten, P.J., 1976. Effect of habitat complexity on population density and species richness in tropical intertidal predatory gastropod assemblages. Oecologia 25(3), 199-210.

Lane, P., 2005. Barbarous tribes and unrewarding gyrations? The changing role of ethnographic imagination in African archaeology. In: Stahl, A.B. (Ed.) African archaeology: A critical introduction. Blackwell Publishing, Oxford, pp.24-54.

Lyman, R.L., 2004. Sampling to redundancy in zooarchaeology: Lessons from the Portland Basin, Northwestern Oregon and Southwestern Washington. Journal of Ethnobiology 24, 329-346.

Lyman RL., 2008. Quantitative Paleozoology. Cambridge University Press, Cambridge.

Magurran, A.E., 1988. Ecological diversity and its measurement. Croom Helm, London.

Magurran, A.E., 2004. Measuring biological diversity. Blackwells, Oxford.

Meehan, B., 1977. Man does not live by calories alone: The role of shellfish in a coastal cuisine. In: Allen, J., Golson, J., Jones, R. (Eds.), Sunda and Sahul. Academic Press, New York, pp. 493-531.

Msemwa, P.J., 1994. An ethnoarchaeological study on shellfish collecting in a complex urban setting. Ph.D. thesis (Brown University).

Mudida, N., Horton, M., 1996. Subsistence at Shanga: The faunal record. In: Horton, M.C. (Ed.) The archaeology of a Muslim trading community on the coast of East Africa. The British Institute in Eastern Africa, London, pp 378-393.

Museum of London Archaeology Service, 1994. Archaeological Site Manual. Museum of London, London.

Nagaoka, L., 2000. Resource depression, extinction, and subsistence change in prehistoric Southern New Zealand. PhD Thesis (University of Washington).

Osborn, A.J., 1977. Aboriginal exploitation of marine food resources. PhD thesis (The University of New Mexico).

Peacock, E., Randklev, C.R., Wolverton, S., Palmer, R.A., Zaleski, S., 2012. The “cultural filter,” human transport of mussel shell, and the applied potential of zooarchaeological data. Ecological Applications 22, 1446-1459.

Perlman, S.M., 1980. An optimum diet model, coastal variability, and Hunter-Gatherer behavior. Advances in Archaeological Method and Theory 3, 257-310.

Prendergast, M.E., Quintana Morales, E.M., Crowther, A., Horton, M.C., Boivin, N.L., 2017. Dietary diversity on the Swahili coast: The fauna from two Zanzibar trading locales. International Journal of Osteoarchaeology, doi: 10.1002/oa.2585.

Punwong, P., Marchant, R., Selby, K., 2013. Holocene mangrove dynamics from Unguja Ukuu, Zanzibar. Quaternary International 298, 4-19.

Radimilahy, C., 1998 Mahilaka: An archaeological investigation of an early town in northwestern Madagascar. Studies in African Archaeology 15. Societas Archaeologica Upsaliensis, Uppsala University, Uppsala.

Richmond, M., 2014. Coastal profile for Zanzibar 2014 region volume II. Samaki Consultants, World Bank, Nordic Development Fund, Dar es Salaam.

Richmond, M.D., 2011. A field guide to the seashores of eastern Africa and the western Indian Ocean islands. SIDA, WIOMSA, Dar es Salaam.

Robin, A., 2008. Encyclopedia of marine gastropods. ConchBooks, Hackenheim, Germany.

Robin, A., 2011. Encyclopedia of marine bivalves, including Scaphopods, Polyplacophora and Cephalopods. ConchBooks, Hackenheim, Germany.

Rowson, B., 2007. Land molluscs of Zanzibar Island (Unguja), Tanzania, including a new species of Gulella (Pulmonata: Streptaxidae). Journal of Conchology 39(4), 425-466.

Rowson, B., B.H. Warren and C. F. Ngereza. 2010. Terrestrial molluscs of Pemba Island, Zanzibar, Tanzania, and its status as an “oceanic” island. ZooKeys 70: 1–39.

Spry, J.F., 1964. The sea shells of Dar es Salaam: Part II Pelecypoda (bivalves). Reprinted from Tanganyika Notes and Records 63. Tanzania Society, Dar es Salaam.

Spry, J.F., 1968. The sea shells of Dar es Salaam. Part I. gastropods. Second revision with supplement. Reprinted from Tanganyika Notes and Records 56. Tanzania Society, Dar es Salaam.

Stiner, M.C., Munro, N.D., Surovell, T.A., 2000. The tortoise and the hare: Small game use, the broad spectrum revolution, and Paleolithic demography. Current Anthropology 41(1), 39-79.

Szabó, K., 2009. Molluscan remains from Fiji. In: Clark, G., Anderson, A. (Eds.) The early prehistory of Fiji. Terra Australis 31. ANU Press, Canberra, pp. 183-211.

Ulrich, W., Almeida-Neto, M., Gotelli, N.J., 2009. A consumer’s guide to nestedness analysis. Oikos 118, 3-17.

Wilson, T.H., Omar, A.L., 1997. Archaeological investigations at Pate. Azania: Archaeological Research in Africa 32(1), 31-76.

Wolverton, S., Lyman, R.L., 2000. Immanence and configuration in analogical reasoning. North American Archaeologist 21(3), 233-247.

Wolverton, S., Otaola, C., Neme, G., Giardina, M., Gil, A., 2015. Patch choice, landscape ecology, and foraging efficiency: The zooarchaeology of Late Holocene Foragers in western Argentina. Journal of Ethnobiology 35(3), 499-518.

Woo, K., Faulkner, P., Ross, A., 2015. The effects of sampling on the analysis of archaeological molluscan remains: A quantitative approach. Journal of Archaeological Science: Reports 7, 730-740.

Wood, M., Panighello, S., Orsega, E.F., Robertshaw, P., van Elteren, J.T., Crowther, A., Horton, M.C., Boivin, N., 2016. Zanzibar and Indian Ocean trade in the first millennium CE: The glass bead evidence. Archaeological and Anthropological Sciences, doi:10.1007/s12520-015-0310-z.

WoRMS Editorial Board, 2016. World Register of Marine Species. Available from http://www.marinespecies.org at VLIZ.

Wright, H.T., 1992 Early Islam, oceanic trade and town development on Nzwani: The Comorian Archipelago in the XIth-XVth Centuries AD. Azania: Archaeological Research in Africa 27(1), 81-128.

Wright, H.T., Sinopoli, C., Wojnaroski, L., Hoffman, E.S., Scott, S.L., Redding, R.W., Goodman, S.M., 1984. Early seafarers of the Comoro Islands: The Dembeni phase of the IXth-Xth centuries AD. Azania: Journal of the British Institute in Eastern Africa 19(1), 13-59.

Wylie, A., 1985. The reaction against analogy. Advances in archaeological method and theory 8, 63-111.

Yesner, D.R., 1980. Maritime hunter-gatherers: Ecology and prehistory. Current Anthropology 21, 727-735.

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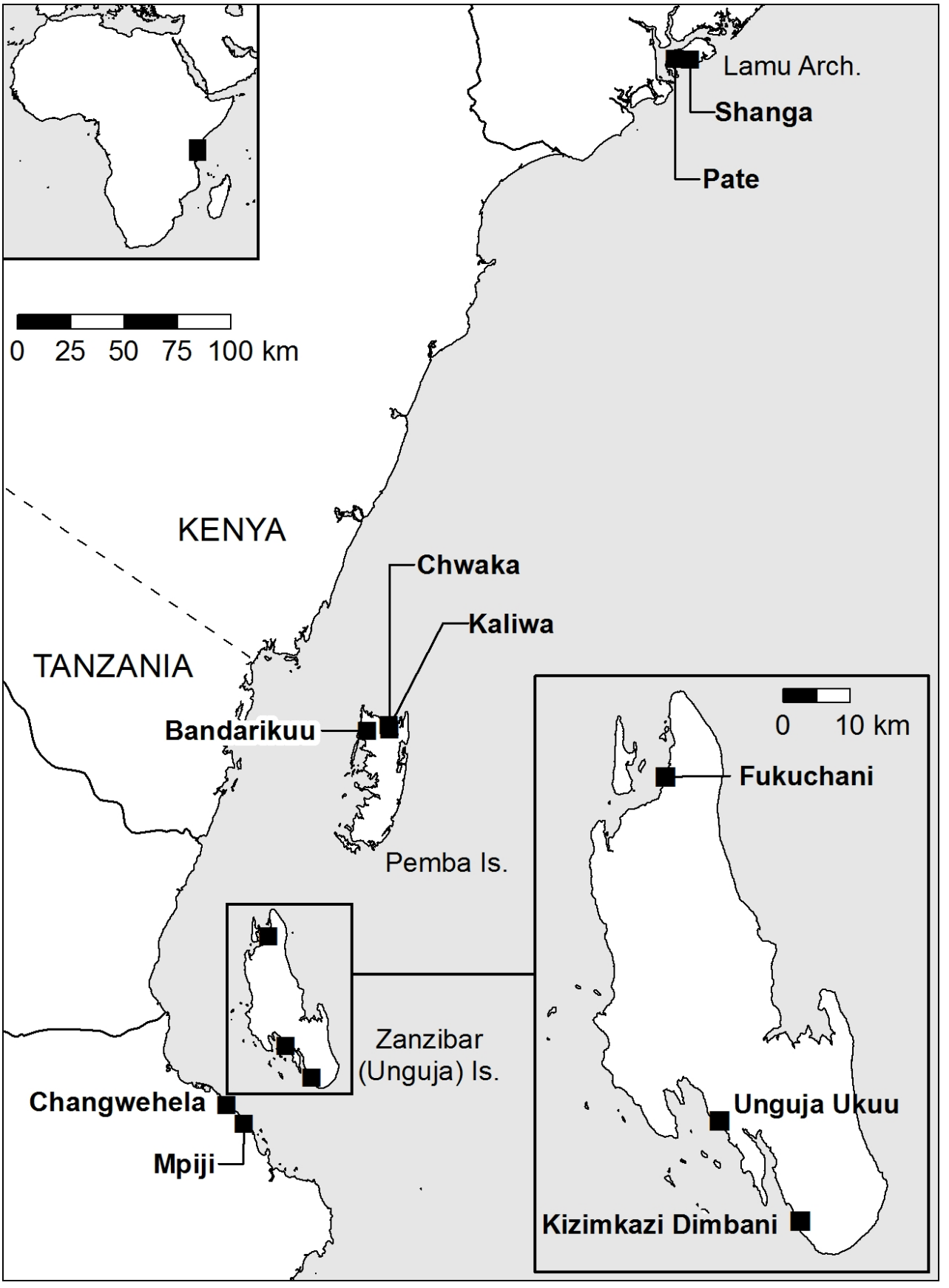
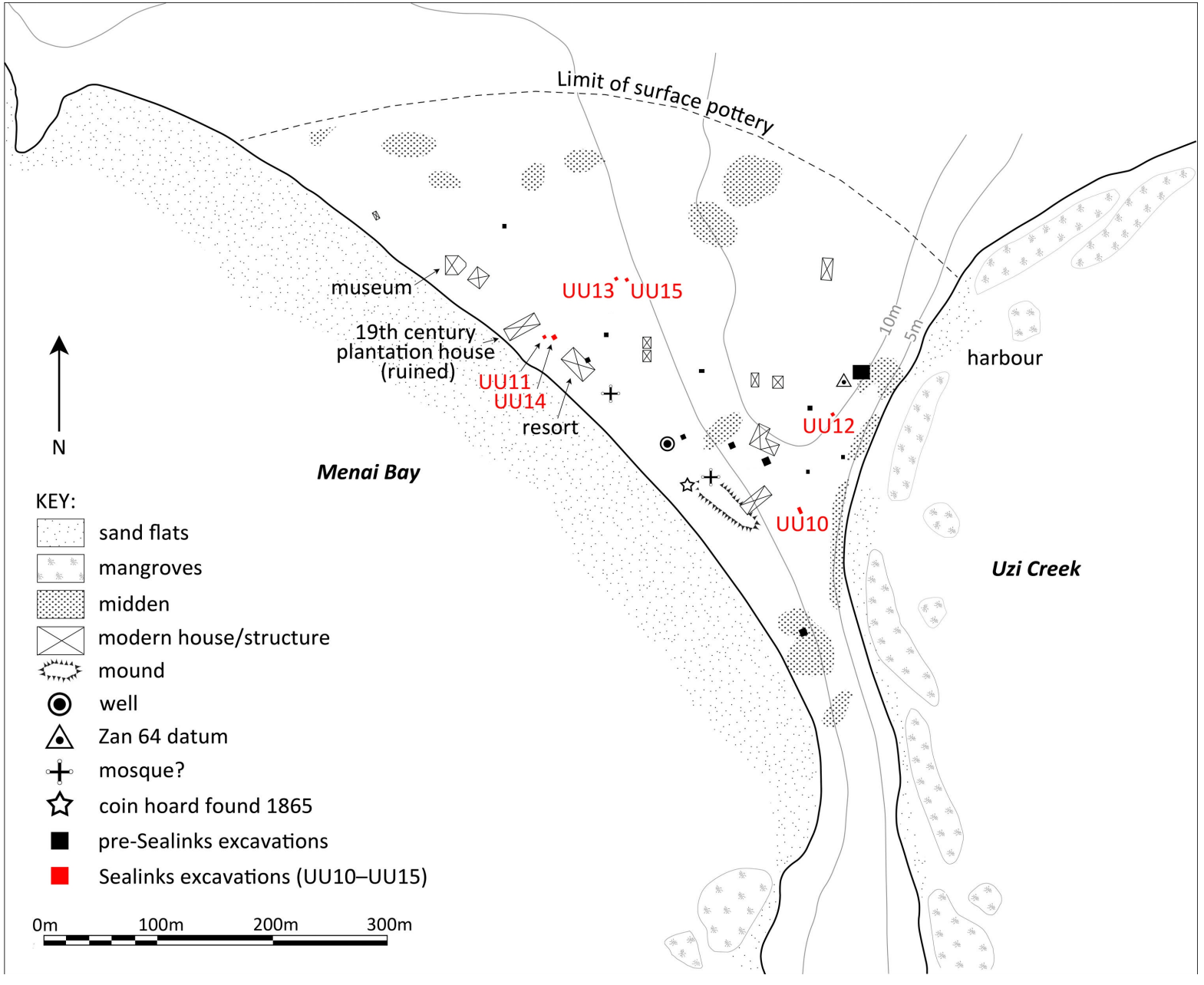
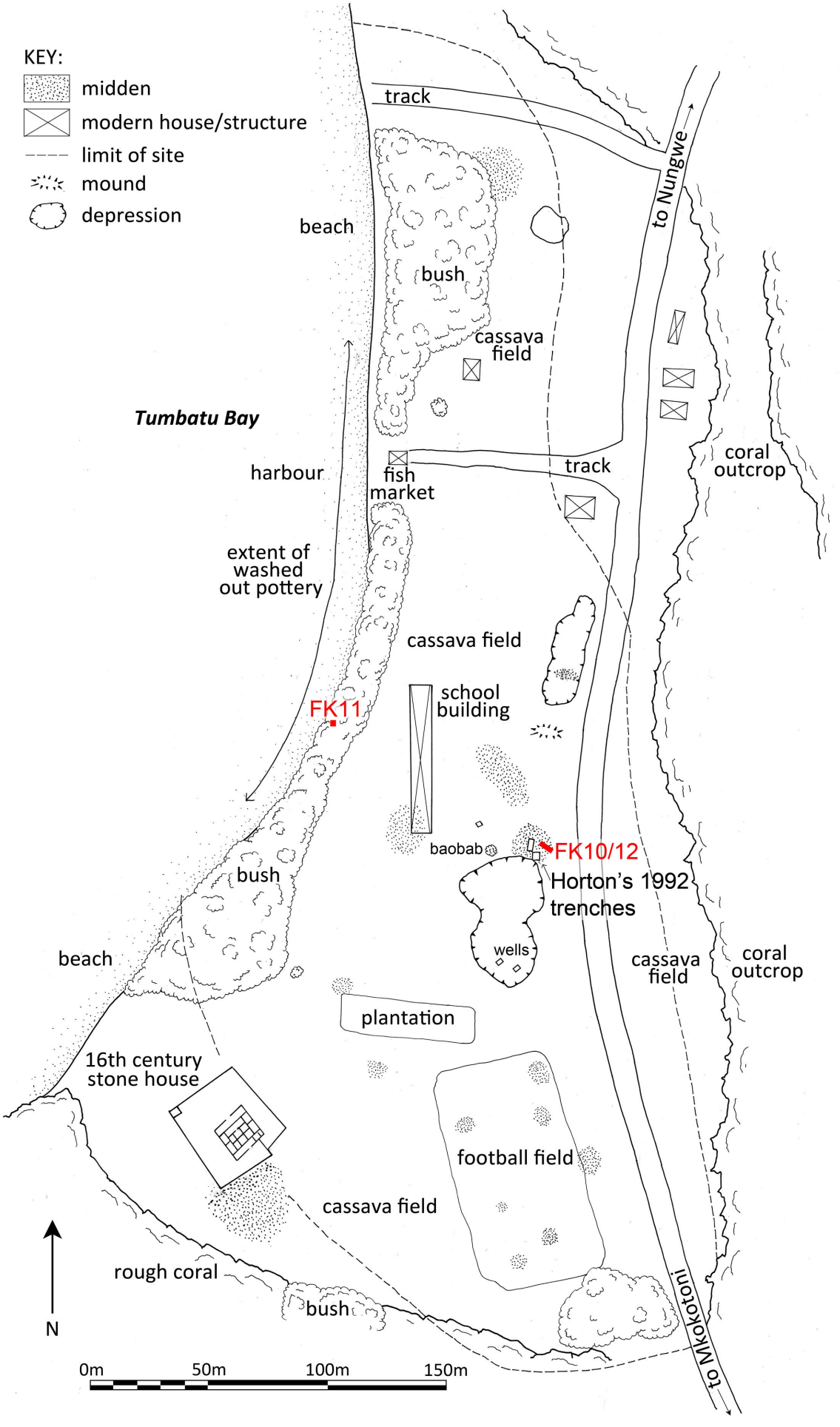
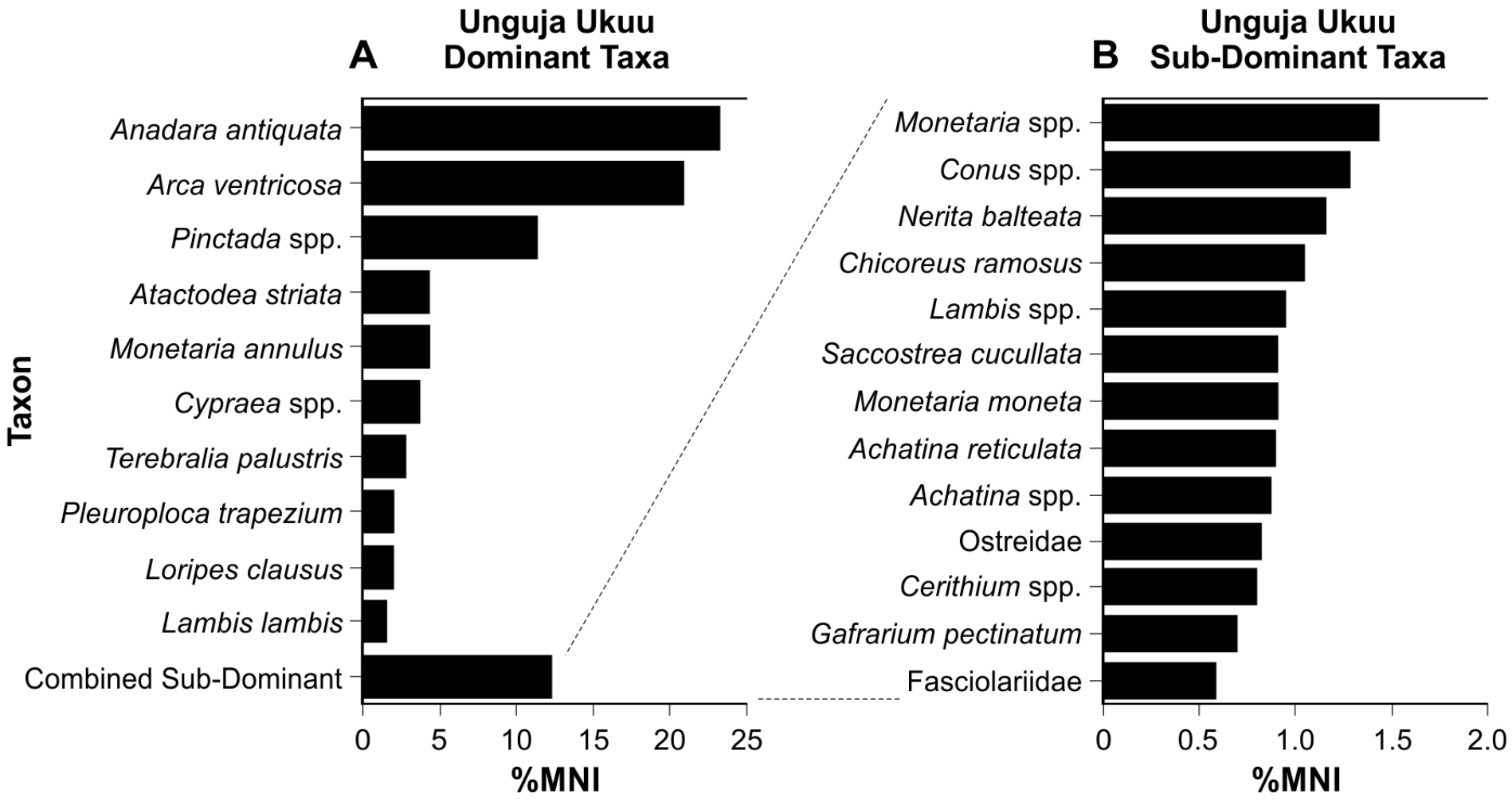
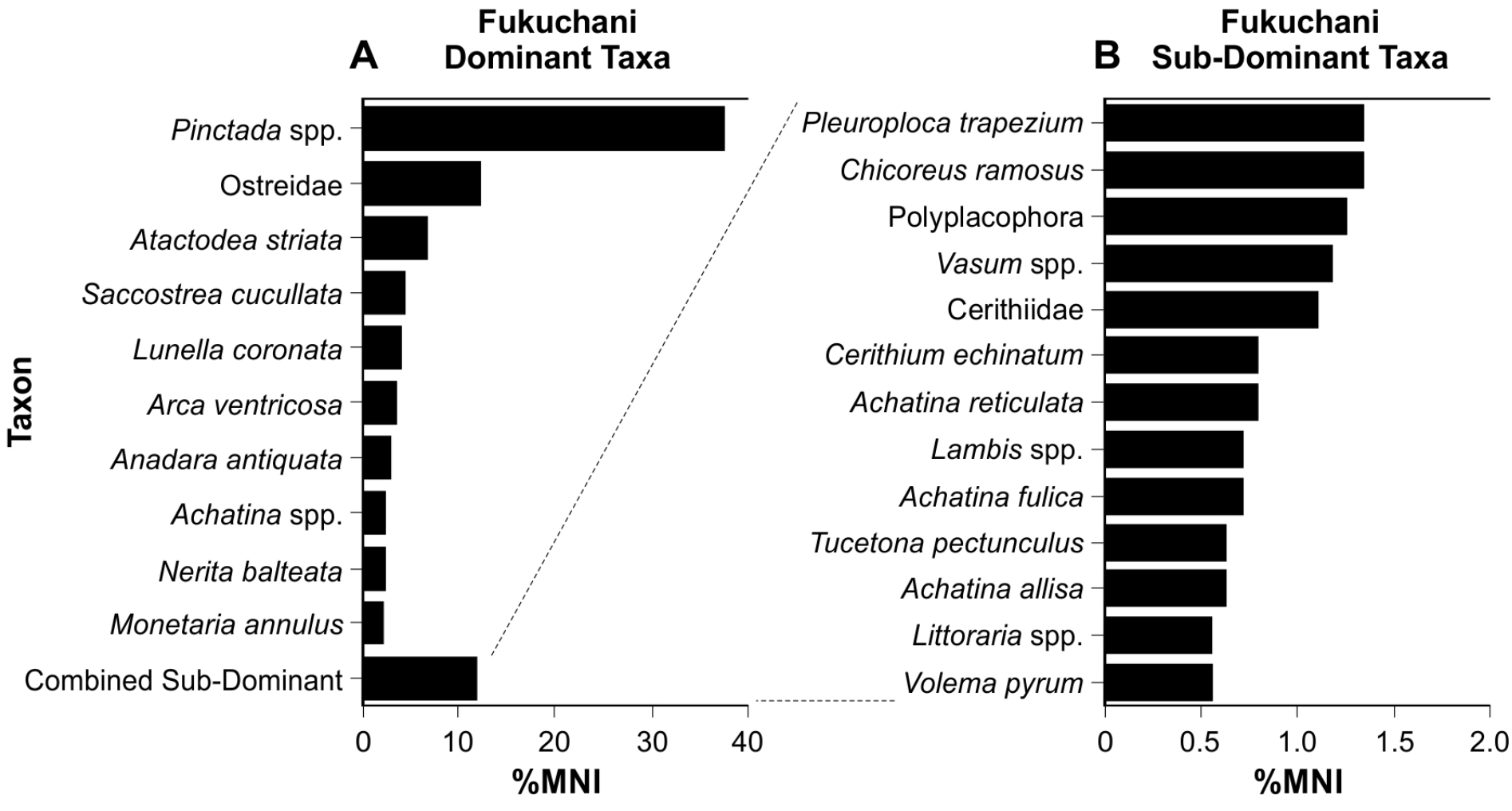
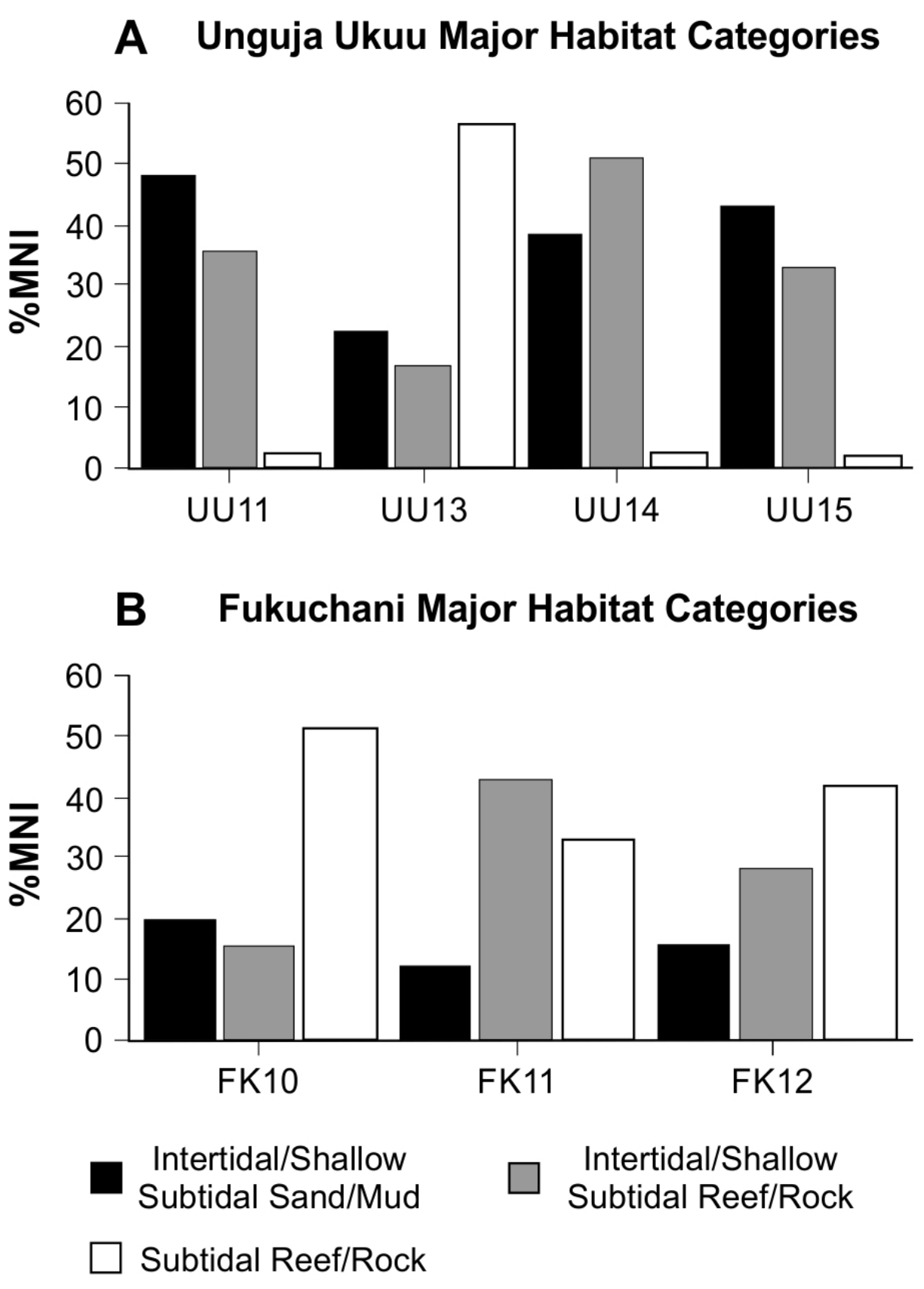

Lamu Arch.
Shanga
Pate
0 25 50 75 100 km
KENYA
Chwaka
Kaliwa
TANZANIA
Bandarikuu
Pemba Is.
0 10 km
Fukuchani
Zanzibar
(Unguja) Is.
Changwehela
Mpiji
Unguja Ukuu
Kizimkazi Dimbani

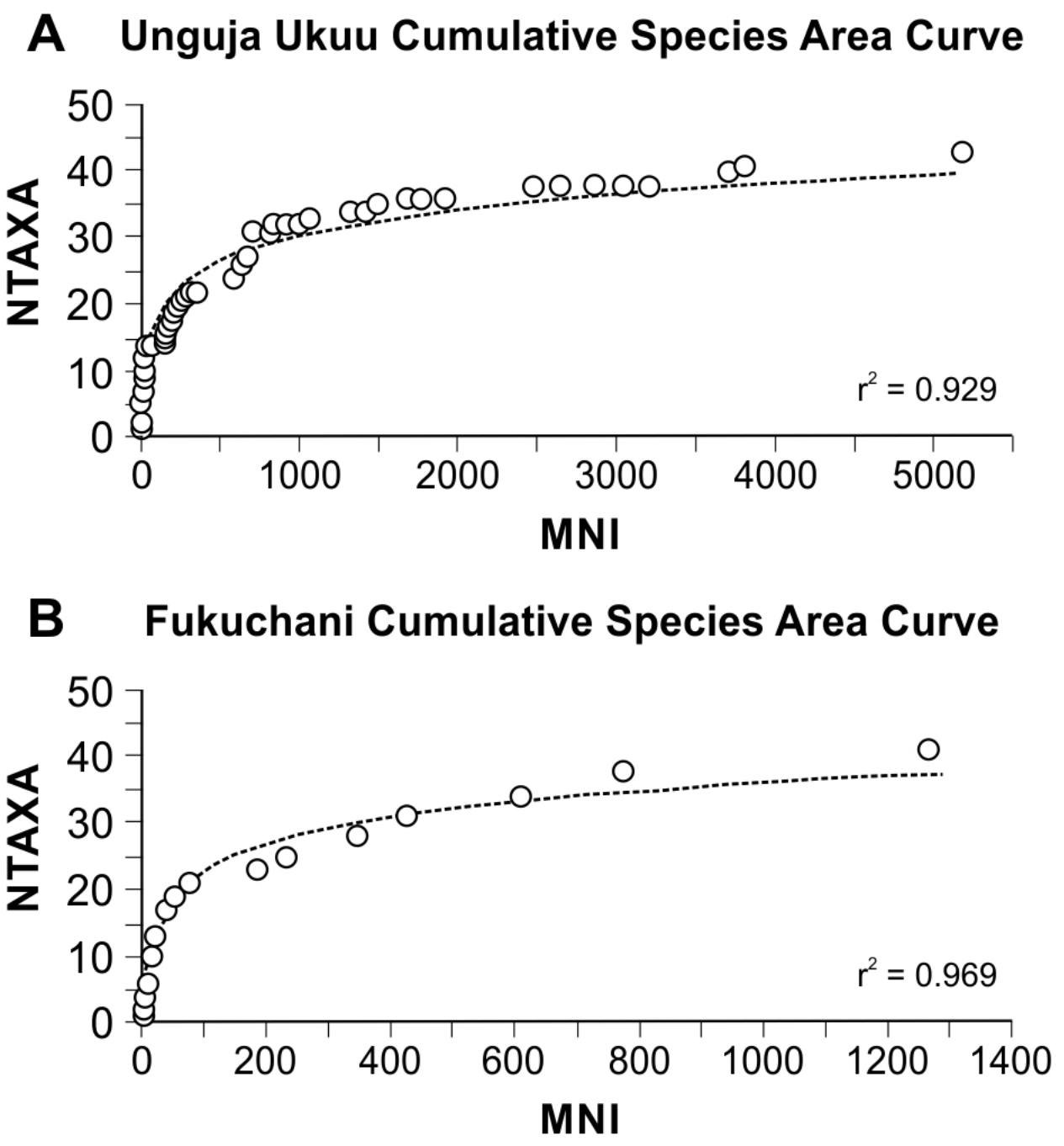

Limit of surface pottery
museum
19th century
plantation house
(ruined)
UU13
UU15
UU11
UU14
resort
UU12
UU10
10m
5m
harbour
Menai Bay
Uzi Creek
N
KEY:
sand flats
mangroves
midden
modern house/structure
mound
well
Zan 64 datum
mosque?
coin hoard found 1865
pre-Sealinks excavations
Sealinks excavations (UU10–UU15)
0m
100m
200m
300m

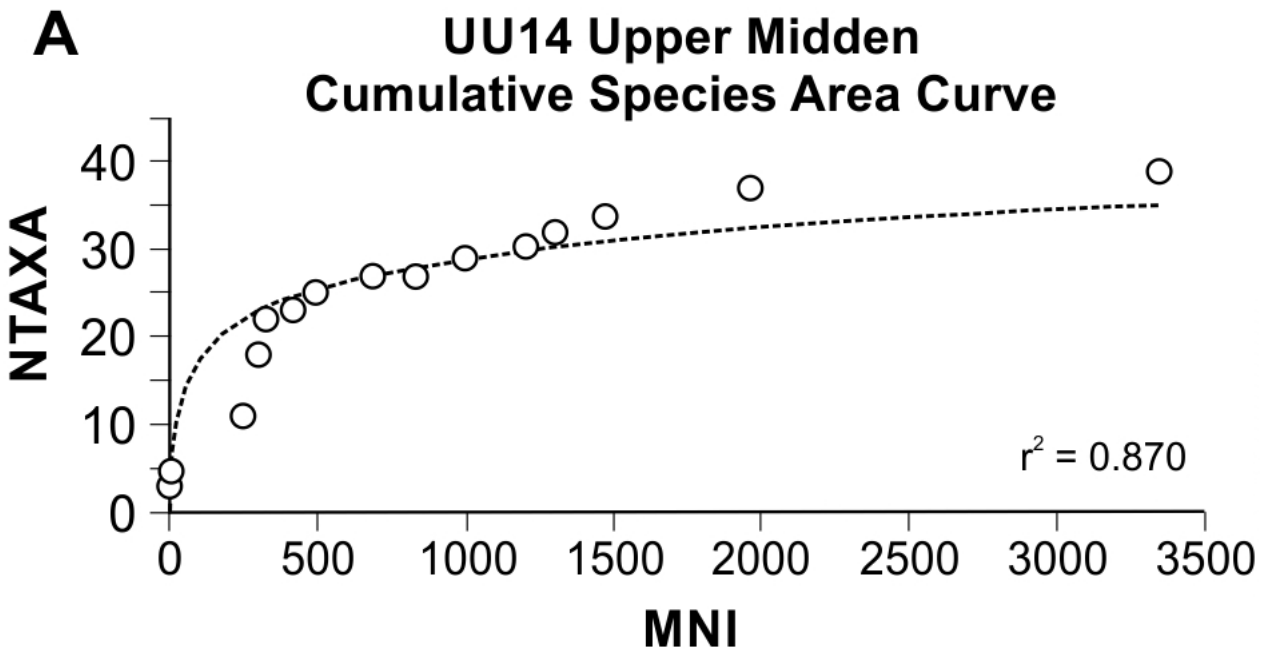

KEY:
midden
modern house/structure
limit of site
mound
depression
track
to Nungwe
beach
bush
cassava field
Tumbatu Bay
harbour
fish market
track
coral outcrop
extent of washed out pottery
cassava field
FK11
school building
baobab
FK10/12
Horton's 1992 trenches
bush
beach
wells
cassava field
coral outcrop
plantation
16th century stone house
football field
cassava field
rough coral
bush
to Mkokotoni
N
0m
50m
100m
150m

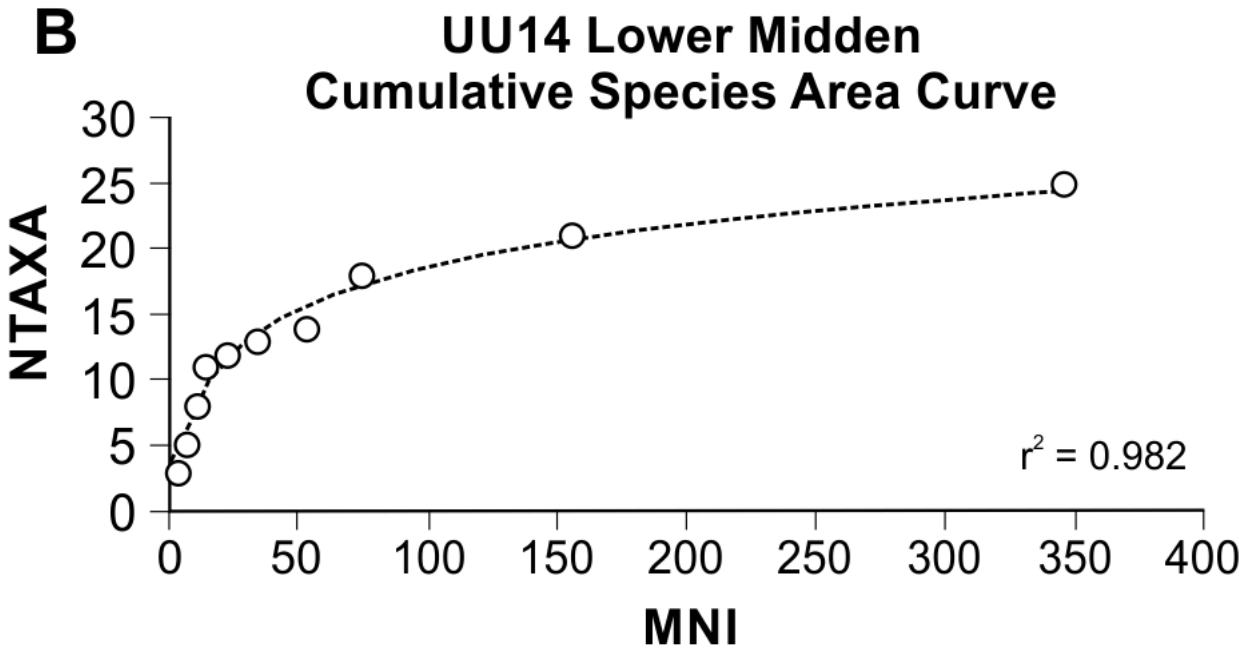

A
Unguja Ukuu
Dominant Taxa
Taxon
Anadara antiquata
Arca ventricosa
Pinctada spp.
Atactodea striata
Monetaria annulus
Cypraea spp.
Terebralia palustris
Pleuroploca trapezium
Loripes clausus
Lambis lambis
Combined Sub-Dominant
0
5
10
15
20
25
%MNI
B
Unguja Ukuu
Sub-Dominant Taxa
Monetaria spp.
Conus spp.
Nerita balteata
Chicoreus ramosus
Lambis spp.
Saccostrea cucullata
Monetaria moneta
Achatina reticulata
Achatina spp.
Ostreidae
Cerithium spp.
Gafrarium pectinatum
Fasciolariidae
0
0.5
1.0
1.5
2.0
%MNI

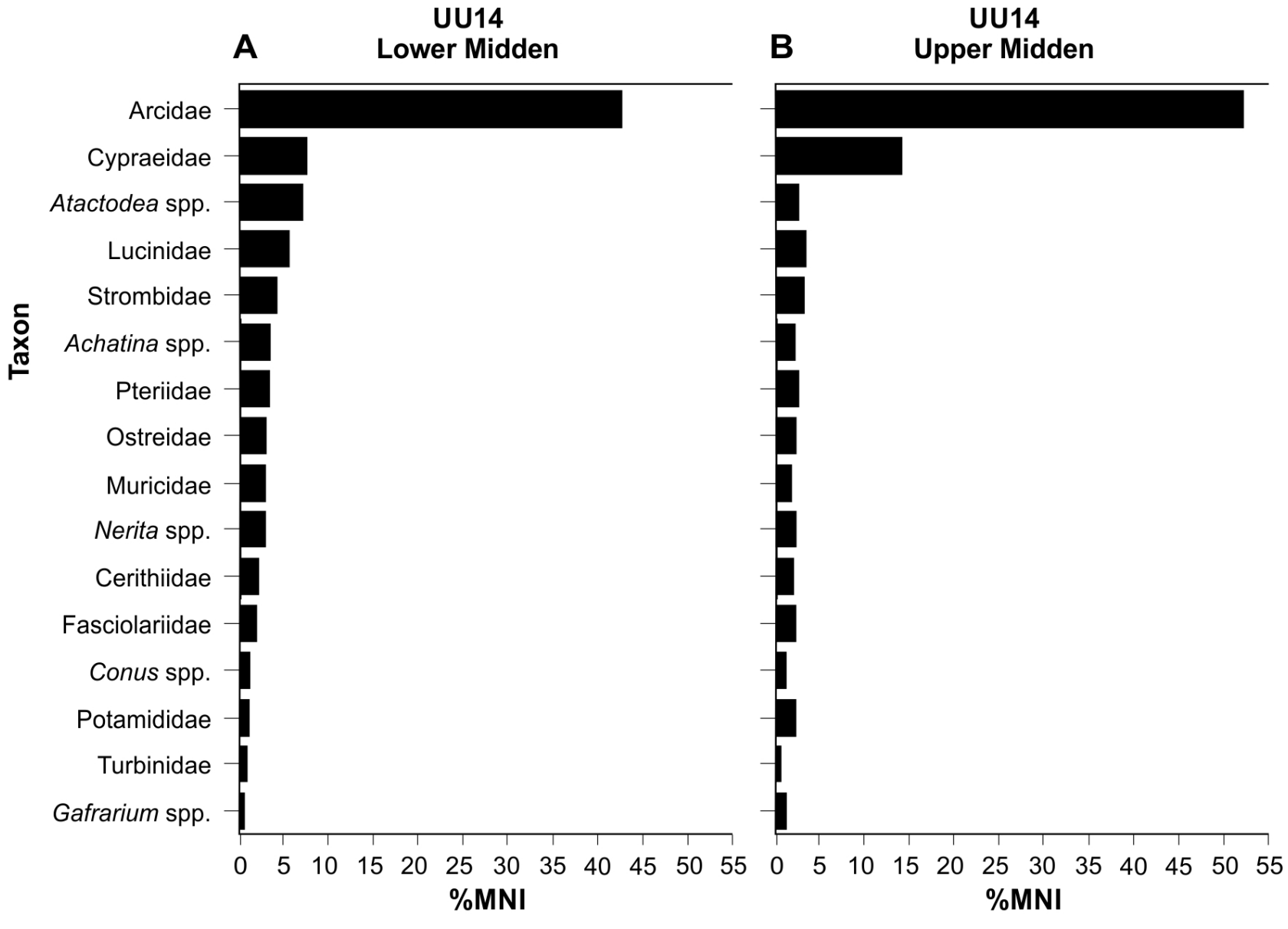

A
Fukuchani
Dominant Taxa
Taxon
Pinctada spp.
Ostreidae
Atactodea striata
Saccostrea cucullata
Lunella coronata
Arca ventricosa
Anadara antiquata
Achatina spp.
Nerita balteata
Monetaria annulus
Combined Sub-Dominant
0
10
20
30
40
%MNI
B
Fukuchani
Sub-Dominant Taxa
Pleuroploca trapezium
Chicoreus ramosus
Polyplacophora
Vasum spp.
Cerithiidae
Cerithium echinatum
Achatina reticulata
Lambis spp.
Achatina fulica
Tucetona pectunculus
Achatina allisa
Littoraria spp.
Volema pyrum
0
0.5
1.0
1.5
2.0
%MNI

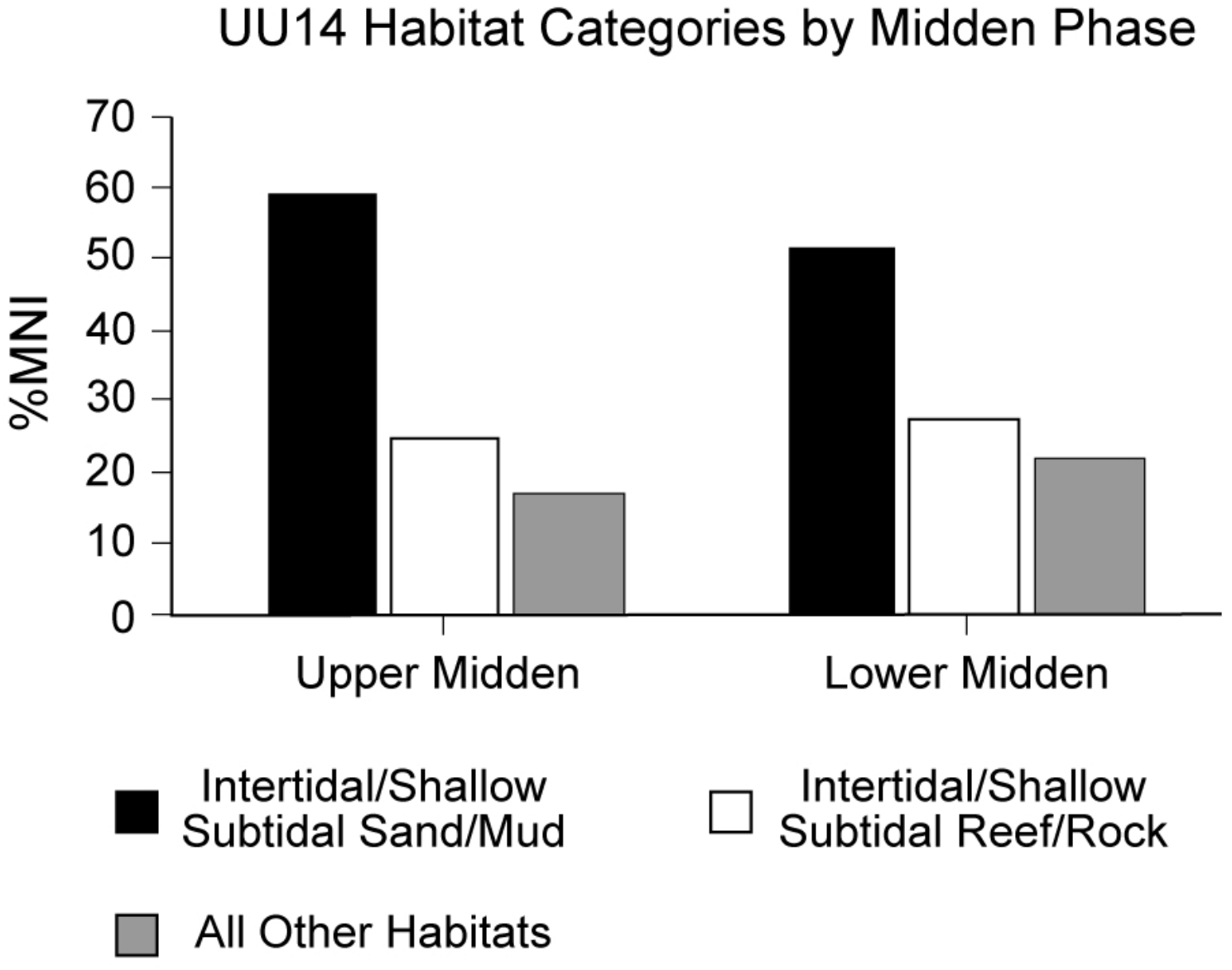

A
Unguja Ukuu Major Habitat Categories
%MNI
60
50
40
30
20
10
0
UU11
UU13
UU14
UU15
B
Fukuchani Major Habitat Categories
%MNI
60
50
40
30
20
10
0
FK10
FK11
FK12
Intertidal/Shallow Subtidal Sand/Mud
Intertidal/Shallow Subtidal Reef/Rock
Subtidal Reef/Rock

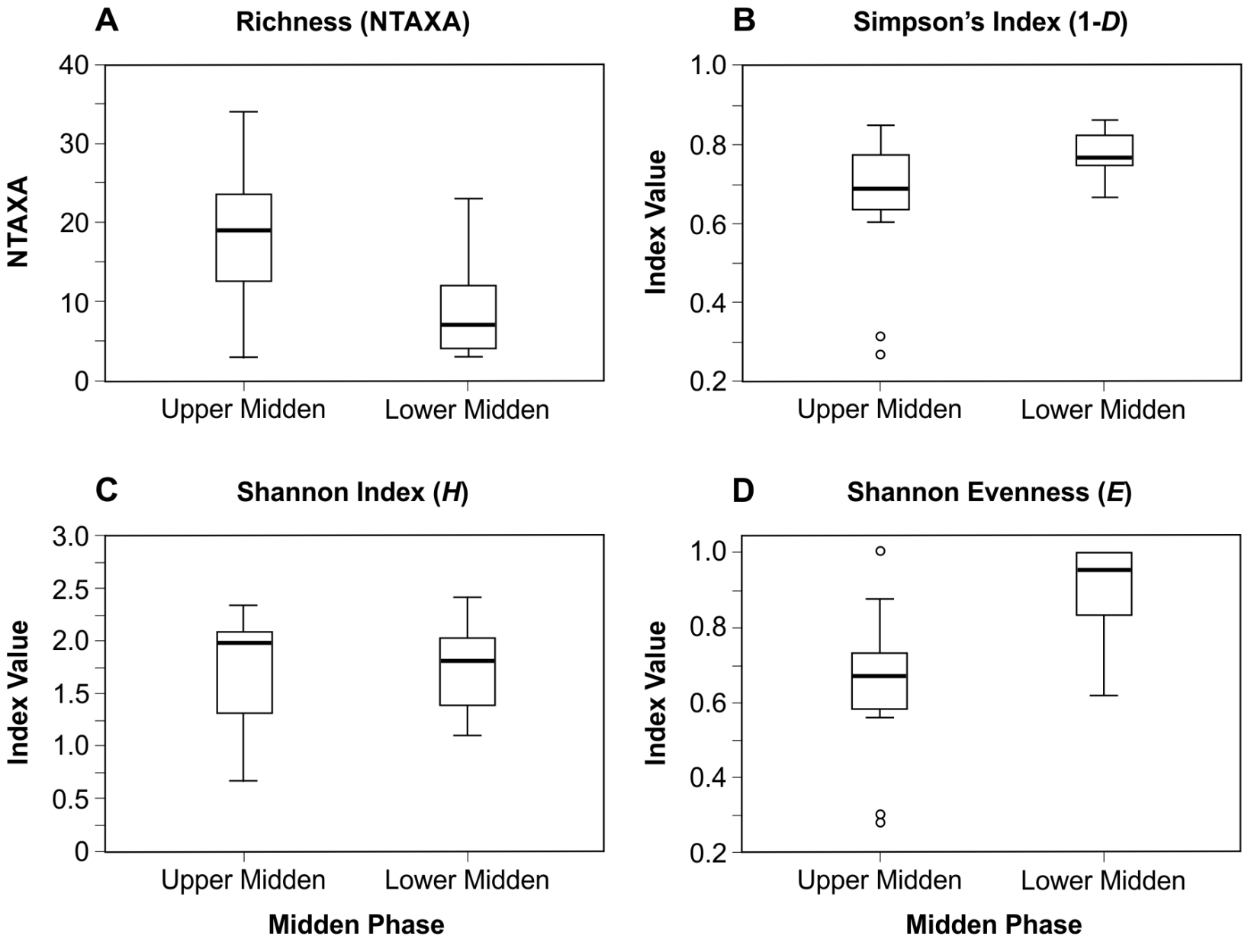

A
Unguja Ukuu Cumulative Species Area Curve
NTAXA
MNI
r2 = 0.929
0
10
20
30
40
50
0
1000
2000
3000
4000
5000
B
Fukuchani Cumulative Species Area Curve
NTAXA
MNI
r2 = 0.969
0
10
20
30
40
50
0
200
400
600
800
1000
1200
1400


A
UU14 Upper Midden
Cumulative Species Area Curve
NTAXA
0
10
20
30
40
0
500
1000
1500
2000
2500
3000
3500
MNI
r2 = 0.870


B
UU14 Lower Midden
Cumulative Species Area Curve
NTAXA
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
MNI
r2 = 0.982


A
UU14
Lower Midden
B
UU14
Upper Midden
Taxon
Arcidae
Cypraeidae
Atactodea spp.
Lucinidae
Strombidae
Achatina spp.
Pteriidae
Ostreidae
Muricidae
Nerita spp.
Cerithiidae
Fasciolariidae
Conus spp.
Potamididae
Turbinidae
Gafrarium spp.
0 5 10 15 20 25 30 35 40 45 50 55
%MNI
0 5 10 15 20 25 30 35 40 45 50 55
%MNI


UU14 Habitat Categories by Midden Phase
%MNI
70
60
50
40
30
20
10
0
Upper Midden
Lower Midden
Intertidal/Shallow Subtidal Sand/Mud
Intertidal/Shallow Subtidal Reef/Rock
All Other Habitats


A
Richness (NTAXA)
NTAXA
40
30
20
10
0
Upper Midden
Lower Midden
B
Simpson's Index (1-D)
Index Value
1.0
0.8
0.6
0.4
0.2
Upper Midden
Lower Midden
C
Shannon Index (H)
Index Value
3.0
2.5
2.0
1.5
1.0
0.5
0
Upper Midden
Lower Midden
Midden Phase
D
Shannon Evenness (E)
Index Value
1.0
0.8
0.6
0.4
0.2
Upper Midden
Lower Midden
Midden Phase

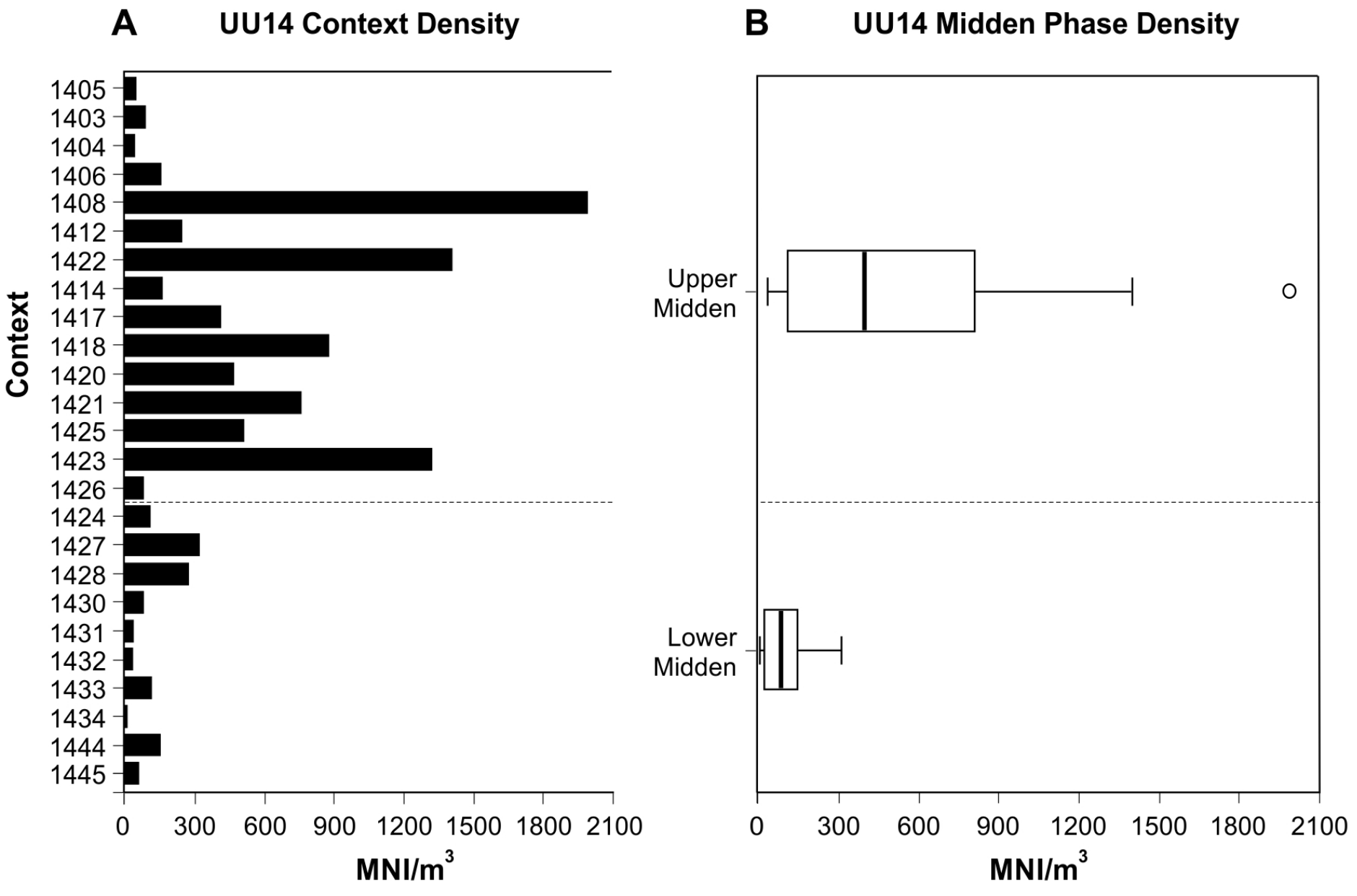

A
UU14 Context Density
Context
1405
1403
1404
1406
1408
1412
1422
1414
1417
1418
1420
1421
1425
1423
1426
1424
1427
1428
1430
1431
1432
1433
1434
1444
1445
0
300
600
900
1200
1500
1800
2100
MNI/m3
B
UU14 Midden Phase Density
Upper Midden
Lower Midden
0
300
600
900
1200
1500
1800
2100
MNI/m3

Table 1: Diversity index results per trench from Unguja Ukuu and Fukuchani

	Unguja Ukuu				Fukuchani		
	UU11	**UU13**	**UU14**	**UU15**	**FK10**	**FK11**	**FK12**
MNI	154	877	3684	453	174	771	320
NTAXA	17	25	39	22	22	36	27
Simpson's Index (1-*D*)	0.774	0.631	0.712	0.801	0.715	0.816	0.809
Shannon Index (*H*)	2.057	1.502	2.039	2.084	1.986	2.298	2.385
Shannon Evenness (*E*)	0.726	0.467	0.557	0.674	0.642	0.641	0.724

Table 2: Descriptive statistics for the diversity index results from Unguja Ukuu and Fukuchani

	Unguja Ukuu				Fukuchani			
	NTAXA	**1-*D***	***H***	***E***	**NTAXA**	**1-*D***	***H***	***E***
N	4	4	4	4	3	3	3	3
Min	17	0.631	1.502	0.467	22	0.715	1.986	0.641
Max	39	0.801	2.084	0.726	36	0.816	2.385	0.724
Median	23.50	0.743	2.048	0.616	27.00	0.809	2.298	0.642
25 percentile	18.25	0.651	1.636	0.490	22.00	0.715	1.986	0.641
75 percentile	35.50	0.794	2.077	0.713	36.00	0.816	2.385	0.724

Table 3: Shell density per total trench and shell-bearing contexts per trench from Unguja Ukuu and Fukuchani

	Unguja Ukuu				Fukuchani	
	UU11	**UU13**	**UU14**	**UU15**	**FK10**	**FK12**
MNI	154	877	3684	453	174	320
Total Trench Volume (m^3)	5.25	2.18	15.48	3.63	1.89	2.01
Shell Density (MNI/m^3)	29	403	238	125	92	159
Shell Bearing Context Volume (m^3)	4.28	1.73	13.63	3.41	0.94	1.57
Shell Density (MNI/m^3)	36	508	270	133	186	204

Table 4: Descriptive statistics for shell density per total trench and shell-bearing contexts per trench from Unguja Ukuu and Fukuchani

	Unguja Ukuu		Fukuchani	
	Total Trench	**Shell Bearing Contexts**	**Total Trench**	**Shell Bearing Contexts**
N	4	2	4	2
Min	29	92	36	186
Max	403	159	508	204
Median	181.5	125.5	201.5	195
25 percentile	53	69	60.25	139.5
75 percentile	361.75	178.75	448.5	220.5

Table 5: Descriptive statistics for the diversity index results from Unguja Ukuu trench UU14 lower and upper midden phases

	UU14 Lower Midden Phase				UU14 Upper Midden Phase			
	NTAXA	**1-*D***	***H***	***E***	**NTAXA**	**1-*D***	***H***	***E***
N	10	10	10	10	15	15	15	15
Min	3	0.667	1.099	0.619	3	0.267	0.661	0.287
Max	23	0.863	2.405	1	34	0.850	2.332	1
Median	9.2	0.773	1.731	0.951	19	0.690	1.977	0.670
25 percentile	4	0.734	1.386	0.828	12	0.626	1.099	0.569
75 percentile	13.75	0.834	2.032	1	24	0.777	2.099	0.734

Table 6: Descriptive statistics for shell density from Unguja Ukuu trench UU14 lower and upper midden phases

	UU14 Lower Midden Phase	**UU14 Upper Midden Phase**
N	10	15
Min	8	33
Max	314	1988
Median	89	400
25 percentile	25.8	81
75 percentile	179.8	873

Table S1: Invertebrate taxonomic categories, habitat designations, trench and total assemblage MNI for Unguja Ukuu

Class	Infraclass/Order/Family	Taxon	Habitat	UU11	UU13	UU14	UU15	Total MNI
Economic								
Bivalvia (Marine)	Anomiidae	Anomiidae			3	4		**7**
	Arcidae	Arcidae		1			1	**2**
		Anadara antiquata		59	61	925	153	**1198**
		Anadara spp.			2			**2**
		Arca ventricosa		8	96	962	16	**1082**
		Barbatia spp.			1	1		**2**
		Barbatia trapezina			3			**3**
	Cardiidae	Cardiidae			2	9	3	**14**
		Maoricardium pseudolima				1		**1**
		Tridacninae				2	2	**4**
		Tridacna maxima				2		**2**
		Vasticardium pectiniforme			1	8		**9**
		Vasticardium rubicundum			4			**4**
	Carditidae	*Beguina gubernaculum*				20	1	**21**
	Chamidae	*Chama* spp.				3		**3**
		Chama brassica			1	2		**3**
		Chama limbula				3		**3**
		Chama pacifica				1		**1**
	Donacidae	*Donax faba*			8			**8**
	Limidae	Limidae				1		**1**
		Lima spp.				1		**1**
		Lima lima				2		**2**
	Lucinidae	Lucinidae					1	**1**
		Codakia spp.				8		**8**
		Codakia punctata				1		**1**
		Codakia tigerina				19		**19**
		Ctena bella				1		**1**
		Loripes clausus				101		**101**
	Mesodesmatidae	*Atactodea* spp.				4		**4**
		Atactodea striata		4	105	106	14	**229**
	Mytilidae	Mytilidae			1	3		**4**

Class	Infraclass/Order/Family	Taxon	Habitat	UU11	UU13	UU14	UU15	Total MNI
		Septifer bilocularis				12		**12**
	Ostreidae	Ostreidae		2		40		**42**
		Saccostrea spp.				3		**3**
		Saccostrea cucullata				47		**47**
	Pectinidae	Pectinidae			2	3		**5**
	Psammobiidae	*Asaphis violascens*				1		**1**
	Pteriidae	Pteriidae				1	7	**8**
		Isognomon spp.		1		2		**3**
		Isognomon ephippium			1			**1**
		Pinctada spp.		3	494	92	2	**591**
	Tellinidae	Tellinidae					1	**1**
		Tellina spp.				11		**11**
		Tellina palatum			1	1		**2**
		Tellina virgata				1		**1**
	Veneridae	*Dosinia* spp.			1			**1**
		Gafrarium spp.			2	5	1	**8**
		Gafrarium pectinatum				36		**36**
		Katelysia spp.				22		**22**
		Lioconcha spp.				2		**2**
		Periglypta spp.				3		**3**
		Periglypta puerpera			1			**1**
Gastropoda (Marine)	Cerithiidae	Cerithiidae			1	16	1	**18**
		Cerithium spp.				41		**41**
		Cerithium caeruleum				5		**5**
		Cerithium columna				1		**1**
		Cerithium echinatum			8			**8**
		Clypeomorus spp.			1	13	3	**17**
		Clypeomorus bifasciata			2			**2**
	Conidae	*Conus* spp.		4	12	43	7	**66**
		Conus litteratus		1				**1**
		Conus textile				1		**1**
	Cypraeidae	Cypraeidae		3	1	7	1	**12**
		Cypraea spp.				195		**195**
		Cypraea tigris		2		11		**13**

Class	Infraclass/Order/Family	Taxon	Habitat	UU11	UU13	UU14	UU15	Total MNI
		Erosaria erosa				3		**3**
		Lyncina vitellus				1		**1**
		Monetaria spp.		2		22	50	**74**
		Monetaria annulus		4		217	6	**227**
		Monetaria moneta		1		39	7	**47**
		Nucleolaria nucleus				1		**1**
	Dentaliidae	*Dentalium* spp.				1		**1**
	Fasciolariidae	Fasciolariidae		9	2	2	17	**30**
		Pleuroploca spp.			3		3	**6**
		Pleuroploca trapezium		3	9	76	17	**105**
	Littorinidae	*Littoraria* spp.				6		**6**
		Littoraria scabra				4		**4**
	Melongenidae	*Volema* spp.				5	4	**9**
		Volema pyrum		1	1	7	1	**10**
	Muricidae	Muricidae		3	1	2	16	**22**
		Chicoreus spp.		2	2	13	1	**18**
		Chicoreus ramosus		3	1	50		**54**
		Mancinella armigera				1		**1**
		Morula spp.			3	1	1	**5**
		Murex spp.		1				**1**
		Thais spp.				1		**1**
		Thalessa virgata			2			**2**
	Nassariidae	*Nassarius* spp.				9		**9**
		Nassarius arcularia plicatus				7		**7**
		Nassarius gemmuliferus				1		**1**
	Naticidae	Naticidae				1		**1**
		Polinices spp.					1	**1**
	Neritidae	*Nerita* spp.		1	1	11	9	**22**
		Nerita albicilla				8	1	**9**
		Nerita balteata			17	43		**60**
		Nerita plicata				4		**4**
		Nerita polita			1	8	5	**14**
		Nerita textilis				10		**10**
	Olividae	*Oliva bulbosa*				1		**1**

Class	Infraclass/Order/Family	Taxon	Habitat	UU11	UU13	UU14	UU15	Total MNI
	Potamididae	Potamididae			1		9	**10**
		Terebralia spp.		3	3	1	5	**12**
		Terebralia palustris		9		74	58	**141**
	Ranellidae	*Cymatium* spp.				2		**2**
		Monoplex spp.		1				**1**
	Strombidae	Strombidae		2			2	**4**
		Gibberulus gibberulus				10		**10**
		Lambis spp.		8	4	22	15	**49**
		Lambis lambis				77		**77**
		Strombus spp.				8		**8**
	Tegulidae	*Tectus pyramis*				1		**1**
	Tonnidae	*Malea* spp.		1				**1**
	Trochidae	Trochidae		1	1	1		**3**
		Gibbula spp.				2		**2**
		Rubritrochus declivis				2		**2**
		Stomatella auricula			1			**1**
	Turbinidae	Turbinidae		2		2	4	**8**
		Lunella spp.		1		1		**2**
		Lunella coronata				13		**13**
		Turbo spp.				5		**5**
		Turbo marmoratus		1		4		**5**
Gastropoda (Terrestrial)	Achatinidae	*Achatina* spp.		5	3	33	4	**45**
		Achatina (Lissachatina) fulica agg.			1	12		**13**
		Achatina (Lissachatina) reticulata		2	2	40	2	**46**
Polyplacophora		Polyplacophora			3	14	1	**18**
Incidental								
Bivalvia (Marine)	Arcidae	*Anadara antiquata* (Juve)				1		**1**
		Arca ventricosa (Juve)				25		**25**
	Carditidae	*Beguina* spp. (Juve)			1			**1**
	Donacidae	Donacidae (<2cm)			22			**22**
	Mesodesmatidae	*Atactodea striata* (Juve)			19			**19**
	Pteriidae	*Pinctada* spp. (Drilled)			1			**1**
Gastropoda (Marine)	Batilariidae	Batilariidae			2	32		**34**

Class	Infraclass/Order/Family	Taxon	Habitat	UU11	UU13	UU14	UU15	Total MNI
	Cancellariidae	*Trigonostoma* spp.					1	**1**
	Cerithiidae	Cerithiidae (Juve)			1			**1**
	Columbellidae	Columbellidae				2		**2**
	Cypraeidae	*Monetaria annulus* (Juve)				1		**1**
	Fasciolariidae	Fasciolariidae (Juve)					2	**2**
	Vermetidae	Vermetidae		6	740	281	6	**1033**
Gastropoda (Terrestrial)	Pomatiasidae	*Tropidophora zanguebarica*				3		**3**
Hexanauplia	Cirripedia	Cirripedia		1	5			**6**
		Striatobalanus spp.				2		**2**
Malacostraca	Decapoda	Decapoda		2	1	4		**7**
Economic Total				**154**	**877**	**3684**	**453**	**5168**
Incidental Total				**9**	**792**	**351**	**9**	**1161**
Total MNI				**163**	**1669**	**4035**	**462**	**6329**

Table S2: Invertebrate taxonomic categories, habitat designations, trench and total assemblage MNI for Fukuchani

Class	Infraclass/Order/Family	Taxon	Habitat	FK10	FK11	FK12	Total MNI
Economic							
Bivalvia (Marine)	Arcidae	*Anadara antiquata*		3	16	12	**31**
		Arca spp.		1		1	**2**
		Arca navicularis			1		**1**
		Arca ventricosa			29	9	**38**
		Barbatia spp.			1		**1**
		Barbatia foliata			1		**1**
	Cardiidae	Cardiidae			2		**2**
	Carditidae	*Beguina gubernaculum*			1		**1**
	Chamidae	*Chama* spp.			1	1	**2**
		Chama brassica				1	**1**
		Chama limbula		1			**1**
	Glycymerididae	*Glycymeris* spp.			2		**2**
		Glycymeris queketti		2			**2**
		Tucetona pectunculus				8	**8**
	Lucinidae	Lucinidae				2	**2**
	Mesodesmatidae	*Atactodea striata*		19	43	18	**80**
	Mytilidae	*Modiolus auricularis*			2		**2**
		Perna spp.			1		**1**
		Septifer bilocularis		4	2		**6**
	Ostreidae	Ostreidae		1	148	3	**152**
		Saccostrea spp.				2	**2**
		Saccostrea cucullata		1	44	5	**50**
	Pectinidae	Pectinidae			1	1	**2**
		Chlamys spp.			1		**1**
	Pteriidae	*Isognomon* spp.			1		**1**
		Pinctada spp.		89	255	131	**475**
	Tellinidae	Tellinidae			3		**3**
	Veneridae	Veneridae			1		**1**
		Gafrarium spp.		1	4		**5**
		Katelysia spp.			2		**2**
Gastropoda (Marine)	Cerithiidae	Cerithiidae			12	2	**14**

Class	Infraclass/Order/Family	Taxon	Habitat	FK10	FK11	FK12	Total MNI
		Cerithium spp.		5			**5**
		Cerithium caeruleum		2			**2**
		Cerithium echinatum			2	8	**10**
		Clypeomorus bifasciata				1	**1**
		Clypeomorus spp.			4	2	**6**
	Conidae	*Conus* spp.		1	1	2	**4**
	Cypraeidae	Cypraeidae			3		**3**
		Cypraea spp.		2			**2**
		Erosaria helvola				1	**1**
		Erosaria spp.				1	**1**
		Melicerona felina			1		**1**
		Monetaria spp.			2		**2**
		Monetaria annulus		1	12	8	**21**
		Monetaria moneta			1		**1**
	Fasciolariidae	Fasciolariidae			4	2	**6**
		Latirus polygonus				1	**1**
		Pleuroploca trapezium		1	9	7	**17**
	Littorinidae	Littorinidae			4	1	**5**
		Littoraria spp.			7		**7**
		Littoraria coccinea			5		**5**
		Littoraria scabra		2			**2**
	Melongenidae	*Volema pyrum*		3	4		**7**
	Mitridae	cf. Mitridae				1	**1**
	Muricidae	Muricidae			5		**5**
		Chicoreus spp.		1	3	2	**6**
		Chicoreus ramosus		1	8	8	**17**
		Murex spp.		2	1		**3**
		Murex brevispina			4		**4**
		Thalessa virgata				1	**1**
	Nassariidae	Nassarius spp.		1	1	1	**3**
		Nassarius coronatus			6		**6**
		Nassarius gemmuliferus			1		**1**
	Naticidae	Naticidae			2		**2**
	Neritidae	*Nerita* spp.		1	2	1	**4**

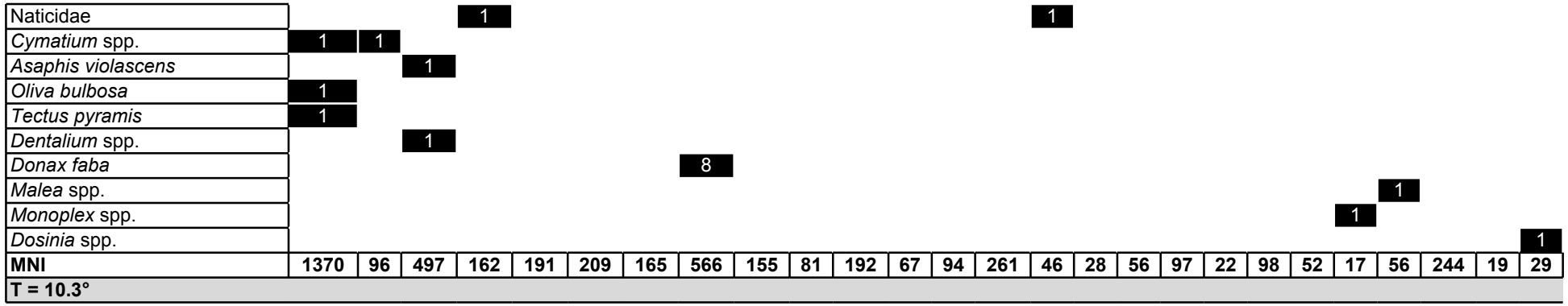
Class	Infraclass/Order/Family	Taxon	Habitat	FK10	FK11	FK12	Total MNI
		Nerita albicilla			2	1	**3**
		Nerita balteata		1	20	3	**24**
		Nerita polita			5		**5**
		Nerita textilis			1		**1**
		Nertia albicilla			2		**2**
	Olividae	Olividae			1		**1**
	Planaxidae	Planaxinae			1		**1**
		Planaxis sulcatus			1	3	**4**
	Potamididae	Potamididae			1		**1**
		Terebralia spp.			1		**1**
		Terebralia palustris			1	2	**3**
	Strombidae	Strombidae				3	**3**
		Canarium urceus		1			**1**
		Gibberulus gibberulus		3			**3**
		Lambis spp.		2	4	3	**9**
		Strombus spp.		2	1		**3**
	Tegulidae	*Tectus fenestratus*			1		**1**
	Tonnidae	cf. *Malea* spp.				3	**3**
	Trochidae	Trochidae			2	1	**3**
	Turbinellidae	*Vasum* spp.				15	**15**
		Vasum ceramicum				1	**1**
		Vasum turbinellus				3	**3**
	Turbinidae	Turbinidae				2	**2**
		Lunella spp.			2		**2**
		Lunella coronata		1	38	6	**45**
		Turbo spp.		2			**2**
Gastropoda (Terrestrial)	Achatinidae	Achatina spp.		2	11	12	**25**
		Achatina (Lissachatina) allisa			1	7	**8**
		Achatina (Lissachatina) fulica agg.		5		4	**9**
		Achatina (Lissachatina) reticulata		3	4	3	**10**
Polyplacophora		Polyplacophora		7	5	4	**16**
Incidental							
Bivalvia (Marine)	Arcidae	*Arca* spp. (Beach Rolled)			1		**1**

Class	Infraclass/Order/Family	Taxon	Habitat	FK10	FK11	FK12	Total MNI
		Barbatia foliata (Epibiont)			1		**1**
	Cardiidae	Cardiidae (Juve)			9		**9**
		Cardiidae (Juve; Drilled)			1		**1**
		Fragum spp. (Juve)			4		**4**
		Fragum spp. (Juve; Drilled)			1		**1**
	Donacidae	Donacidae (<2cm)			9		**9**
		Donacidae (Juve)			1		**1**
	Glycymerididae	Glycymerididae (Juve)			1		**1**
	Lucinidae	Lucinidae (Juve)			3		**3**
	Mactridae	Mactridae (Juve)			1		**1**
		Mactridae (Juve; Drilled)			1		**1**
	Mesodesmatidae	*Atactodea striata* (Juve)			22		**22**
	Mytilidae	*Perna* spp. (Juve)			2		**2**
		Septifer bilocularis (Drilled)			1		**1**
	Veneridae	Veneridae (Juve; Drilled)			1		**1**
		Chione spp. (Juve)			1		**1**
Gastropoda (Marine)	Batilariidae	Batilariidae		3	1	7	**11**
		Batilariidae (Drill)				1	**1**
	Cerithiidae	Cerithiidae (Juve)			52		**52**
	Fissurellidae	Fissurellidae (Juve)			1		**1**
		Diodora ruppellii		3		1	**4**
	Hipponicidae	Hippocinidae			3		**3**
		Hipponix spp.		1			**1**
	Littorinidae	Littorinidae (Juve)			8		**8**
	Neritidae	*Nerita* spp. (Juve)			5		**5**
		Nerita balteata (Hermit)			1		**1**
	Olividae	Olividae (Juve; Beach Rolled)			1		**1**
	Patellidae	Patellidae (Juve)			2		**2**
	Vermetidae	Vermetidae		93	35	82	**210**
Gastropoda (Terrestrial)	Cerastidae	*Edouardia* spp.			3		**3**
	Maizaniidae	*Maizania zanzibarica*		2	17		**19**
	Pomatiasidae	*Tropidophora zanguebarica*			55		**55**
	Subulinidae	Subulinidae			21		**21**
		Homorus (Subulona) usagarica			1		**1**

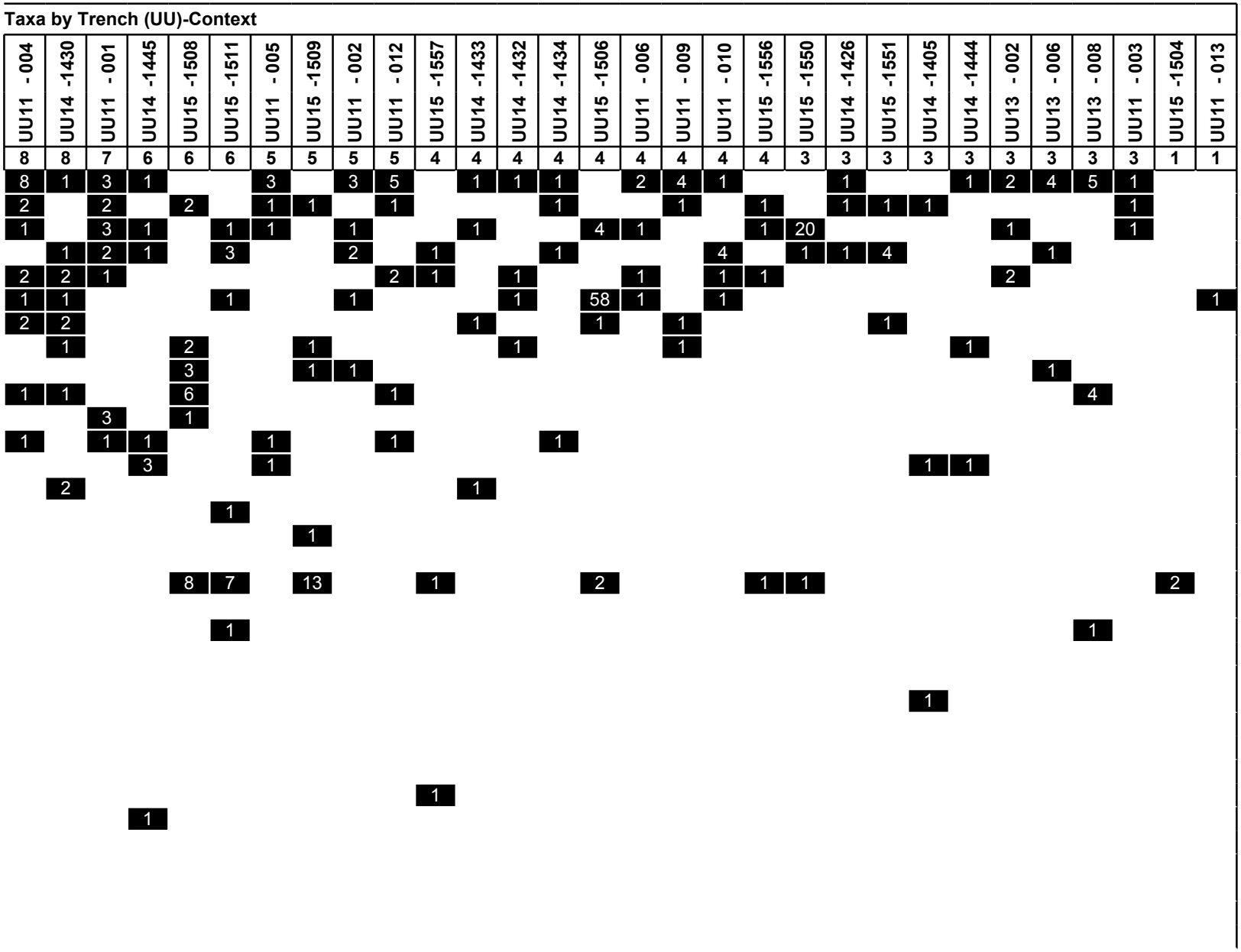
Class	Infraclass/Order/Family	Taxon	Habitat	FK10	FK11	FK12	Total MNI
		Pseudoglessula subolivacea agg.			2		**2**
		Rachidinia spp.			1		**1**
		Subulina intermedia			1		**1**
	Urocyclidae	*Trochonanina mozambicensis*			6		**6**
Hexanauplia	Cirripedia	Cirripedia		1	410	1	**412**
Malacostraca	Decapoda	Decapoda		1	4	1	**6**
Economic Subtotal				**174**	**771**	**320**	**1265**
Incidental Total				**104**	**690**	**93**	**887**
Total MNI				**278**	**1461**	**413**	**2152**

Table S3: Nestedness matrix for invertebrate taxa from Unguja Ukuu by context per trench (UU11, UU13, UU14 and UU15). Black cells indicate presence of that taxon within each co

Taxon	Unguja Ukuu Invertebrate T																									
	UU14 -1423	UU14 -1418	UU14 -1408	UU14 -1412	UU14 -1428	UU14 -1425	UU14 -1421	UU13 - 005	UU14 -1406	UU14 -1424	UU14 -1420	UU14 -1404	UU14 -1414	UU13 - 007	UU15 -1510	UU14 -1422	UU15 -1507	UU15 -1502	UU14 -1427	UU15 -1501	UU14 -1417	UU11 - 011	UU11 - 007	UU14 -1403	UU14 -1431	UU13 - 004
NTAXA	**34**	**24**	**24**	**24**	**23**	**23**	**23**	**22**	**22**	**19**	**19**	**18**	**17**	**16**	**15**	**13**	**13**	**13**	**12**	**12**	**12**	**11**	**11**	**10**	**9**	**8**
Arcidae	740	36	411	66	104	108	78	102	93	24	82	27	54	38		9			9		32	3	35	3	5	12
Muricidae	24	2	3	3	4	3	3	5	4	3	9	1	1	2	1		2	3	1	7	1	1		1	2	2
Potamididae	31	1	1	2	2	2	1	2	1	1	12	1	1	1	1		4	12		29		1	3	17		
Fasciolariidae	18	11	4	9	2	4	5	3	2	2	3	3	3	1	1		4	12		11			4	7	1	9
Strombidae	39	4	3	4	9	10	13	1	4	2	12	1	5		1	2	2	7		5	5	1	2		1	1
Cypraeidae	126	12	15	19	15	19	9	1	12	8	30	4	11			2	2	1	1	2	2	5	2	208	1	
Achatina spp.	39	5	5	4	6	5	3	5	2	2	3	2	2	1		1	2	1	1	1	1	1	3		1	
Atactodea spp.	45	2	5	5	9	7	4	97	1	11	6	2	5	8	10			1	2			1	2	3		
Nerita spp.	33		7	13	2	5	4	16	3	3	4	1		1	2	1	4	1	1	4				2	5	1
Pteriidae	44	2	3	2	6	9	11	295		5	5	1	2	196	2	3			1	1		1	1			
Conus spp.	22	3	1	2	2	5	3	6	2	2		1		4	4		1		1	1			2			2
Turbinidae	5	1	1	4		4			4	1	2				1		1	1		1					1	
Ostreidae	10	1	11	8	6	2	14		1		7	16	3			1					3	1			2	
Lucinidae	67	1	4	4	8	13	2		5	7	8	1	1			3	1		2		1					
Cerithiidae	49	5		3	3	3	2	8	2	5	1	1		3	3	1			1							1
Cardiidae	5	1	1	3	1		1	6	1	1	1	1	1	1	1		1		1							
Gafrarium spp.	17	1	2	2	2	1	5	2	1	1	4	1	1			1		1			2					
Anomiidae			4					2						1	16		31	53		35						
Volema spp.	2		1	2	1	1	1	1					1		1	2	1	3				1		1		
Polyplacophora	4	1	2		1	1		2	1	1	1		1			1										
Tellinidae	1	1		1	1		1	1	6	1					1						1					
Beguina gubernaculum	2	1	5	1			1		7			2						1			1					
Katelysia spp.	11				3	2	1		1				1								1			1		
Mytilidae	7		3		1	1				1				1		1			1							
Nassarius spp.	7			2	2	2	1		1		1	1														
Trochidae	3	1					1	1						1									1			
Tridacninae	1	1		1		1														1						
Pectinidae	1	1						1						1												
Limidae	1								1				1											1		
Periglypta spp.	1					1	1	1																		
Chama spp.	5		3	1										1												
Littorinidae	7				1																2					
Lioconcha spp.		1									1															


Naticidae
Cymatium spp.
Asaphis violascens
Oliva bulbosa
Tectus pyramis
Dentalium spp.
Donax faba
Malea spp.
Monoplex spp.
Dosinia spp.
MNI
1370 96 497 162 191 209 165 566 155 81 192 67 94 261 46 28 56 97 22 98 52 17 56 244 19 29
T = 10.3°

ntext, with white numbers representing the sample size per taxon within each context by MNI



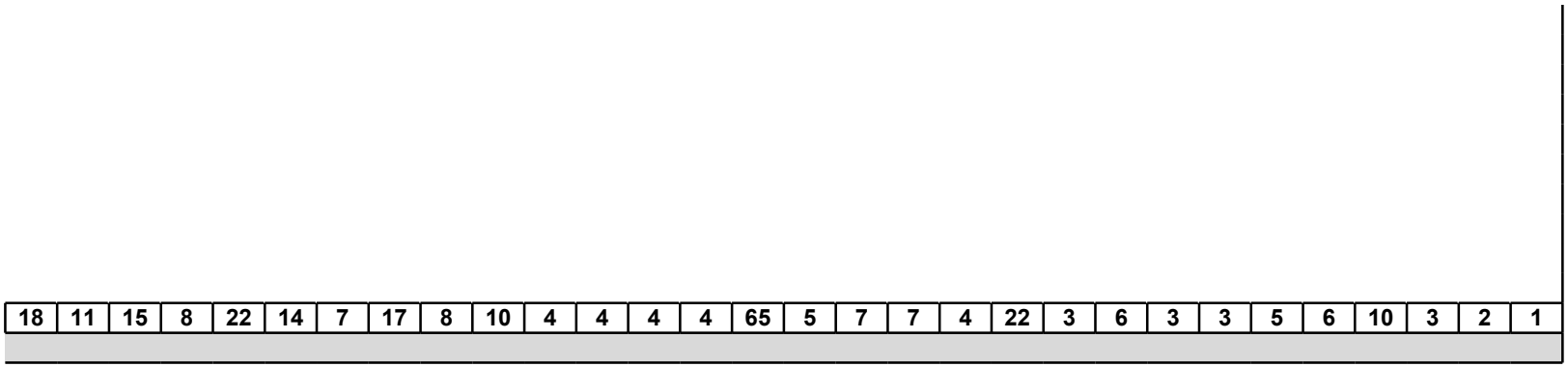

18 11 15 8 22 14 7 17 8 10 4 4 4 4 65 5 7 7 4 22 3 6 3 3 5 6 10 3 2 1

Table S4: Nestedness matrix for invertebrate taxa from Fukuchani by context per trench (FK10, FK11 and FK12). Black cells ir

Taxon	Fukuchani Invertebrate Taxa by Trench (FK)-Context																
	FK11-006	FK11-005	FK12-002	FK11-007	FK12-003	FK10-003	FK10-002	FK12-001	FK10-007	FK11-004	FK11-010	FK11-002	FK11-008	FK11-001	FK12-004	FK10-005	FK10-001
NTAXA	**29**	**28**	**26**	**20**	**19**	**18**	**16**	**14**	**10**	**9**	**7**	**5**	**3**	**2**	**1**	**1**	**1**
Achatina spp.	8	3	9	2	14	2	7	3	1	1	1	1					
Anadara antiquata	7	2	6	2	5	1	1	1	1	3			1	1			
Atactodea striata	13	25	11	1	5	8	10	2	1	2		2					
Nerita spp.	12	4	2	13	2	1		1	1		1	1	1				
Cypraeidae	14	4	6	1	2	1		1	1						1		1
Strombidae	2	1	4	1	1	2	5	1		1						1	
Pinctada spp.	192	56	82	5	45	14	69	4	6	2							
Ostreidae	163	24	6	4	2	1	1	2		1							
Turbinidae	17	3	4	17	4	2	1				2		1				
Arca spp.	10	2	6	16	3		1	1			1	1					
Cerithiidae	10	6	6	1	7	1	5		1		1						
Muricidae	10	7	5	3	5	2	2	1		1							
Fasciolariidae	6	3	8		1	1		1		4							
Littorinidae	9	3	1	3		1			1			1					
Polyplacophora	3	1	4	1		2	4		1								
Veneridae	1	4					1			1	1						
Nassarius spp.	5			2			1	1			1						
Septifer bilocularis	1	1				1	2		1								
Potamididae	1	1	1		1									1			
Planaxinae	1	1	2		1												
Conus spp.			2	1		1											
Tucetona pectunculus			4		3			1									
Trochidae	1	1	1														
cf. *Malea* spp.			1		1			1									
Chama spp.		1	2				1										
Pectinidae	1	1	1														
Volema pyrum				4		2	1										
Glycymeris spp.	1	1				2											
Lucinidae			1		1												
Tellinidae	1	2															
Cardiidae		1		1													
Barbatia spp.	1	1															
Naticidae	1	1															
Vasum spp.			7		12												
Tectus fenestratus	1																
Isognomon spp.	1																
cf. Mitridae			1														
Modiolus auricularis	2																
Beguina gubernaculum				1													
Perna spp.		1															
Olividae				1													
MNI	**495**	**161**	**183**	**80**	**115**	**45**	**112**	**21**	**15**	**16**	**8**	**6**	**3**	**2**	**1**	**1**	**1**
T = 11.7°																	

ndicate presence of that taxon within each context, with white numbers representing the sample size per taxon within e

ach context by MNI

Table S5: Nestedness matrices for invertebrate taxa from Unguja Ukuu trench UU14 lower and upper midden phases by cor

	UU14 - Lower Midden Contexts							
Taxon	**1428**	**1424**	**1427**	**1431**	**1430**	**1445**	**1434**	**1433**
NTAXA	**23**	**19**	**12**	**9**	**8**	**6**	**4**	**4**
Arcidae	104	24	9	5	1	1	1	1
Achatina spp.	6	2	1	1	2			1
Atactodea spp.	9	11	2		1			
Cypraeidae	15	8	1	1	1			
Fasciolariidae	2	2		1	1	1	1	
Lucinidae	8	7	2		2			1
Muricidae	4	3	1	2			1	
Strombidae	9	2		1	2			
Nerita spp.	2	3	1	5				
Turbinidae		1		1		1	1	
Ostreidae	6			2		3		
Potamididae	2	1				1		1
Pteriidae	6	5	1		1			
Cerithiidae	3	5	1					
Mytilidae	1	1	1					
Cardiidae	1	1	1					
Conus spp.	2	2	1					
Gafrarium spp.	2	1						
Tellinidae	1	1						
Polyplacophora	1	1						
Pectinidae						1		
Katelysia spp.	3							
Littorinidae	1							
Nassarius spp.	2							
Volema spp.	1							
MNI	**191**	**81**	**22**	**19**	**11**	**8**	**4**	**4**
T = 16.1°								

ntext. Black cells indicate presence of that taxon within each context, with white numbers representing the sample size per t

1432	1444
4	**3**
1	1
1	1
1	
1	
	1

taxon within each context by MNI

er Midden Contexts							
1420	1404	1414	1422	1417	1403	1426	1405
19	18	17	13	12	10	3	3
82	27	54	9	32	3	1	
9	1	1		1	1	1	1
7	16	3	1	3			1
30	4	11	2	2	208		
8	1	1	3	1			
3	3	3			7	1	
4	1	1	1	2			
3	2	2	1	1			
12	1	5	2	5			
12	1	1			17		
6	2	5			3		
5	1	2	3				
4	1		1		2		
1	1	1					
1	1		1				
	2			1			
	1						
1		1	1				
		1		1	1		1
		1	2		1		
2							
1	1						
				1			
		1			1		
			1				
				2			
1							
192	67	94	28	52	244	3	3